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PERKIN-ELMER

Plasma Products Division

MP MASTER
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PERKIN-ELMER

Plasma Products Division
P.O. Box 10920
Palo Alto, California 94303

WESTERN ELECTRIC
P.O. NO. LS 481162

SERIAL NO. 999-000-259
M.O. NO. 23470
S.O. NO. 24546

WARNING

FAILURE TO PROVIDE ADEQUATE CONTINUED WATER TO THIS SYSTEM WILL RESULT IN DAMAGE TO THE HIGH VACUUM PUMP AND/OR INTERNAL PARTS OF THE SYSTEM. FAILURES CAUSED BY LACK OF WATER OR INADEQUATELY FILTERED WATER ARE NOT COVERED BY WARRANTY.

WATER SUPPLIED TO THIS SYSTEM MUST BE FILTERED, AND MUST NOT CONTAIN CORROSIVE ELEMENTS. DEIONIZED FILTERED WATER (USING A LARGE 100-MICRON FILTER) IS RECOMMENDED. A LESS DESIRABLE METHOD IS TO USE THE SAME FILTER WITH WATER THAT HAS A PH OF 8-10.

PREFACE

This System Manual contains information pertaining to the installation, programming, operation, troubleshooting, and maintenance of the Perkin-Elmer Model 4410 Delta™ Cathode Production Sputtering System.

Chapter 1 contains the introduction and description of the Model 4410 processing system, its modules, functions, and specifications. The installation, shipping, inspection, and assembly are discussed in Chapter 2. Information regarding the System Engineer's Guide, programming, and configuration is presented in Chapter 3.

Chapter 4, which contains the Operator's Guide, provides the essential guidelines for the operation of the Model 4410 System. In addition, Chapter 4 is designed to be a separate entity so that it can be removed in its entirety for use as an operating manual without disrupting the continuity and the flow of this system manual. Information pertaining to troubleshooting and maintenance is found in Chapter 5. The drawings and schematics are contained in Chapter 6, and the appendices are contained in Chapter 7.

Perkin-Elmer Plasma Products Division (PPD) has attempted to provide a precise, accurate, and detailed system manual to its customers. In the event of addition of options and of changes occurring in the future which may affect the system and its design, Model 4410 System manual holders will promptly be provided with errata sheets and instructions on how to update their manual.

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PROGRAMMABLE POWER STABILIZER

APPENDIX B
MICROPROCESSOR PROCESS CONTROLLER

CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

The Perkin-Elmer Model 4410 Delta™ Cathode Production Sputtering System is a unique, advanced design which, when combined with a microprocessor, offers a completely automatic sputtering deposition capability, thus eliminating process variation due to operator errors. Programmed automation allows the system to handle almost any sputter deposition requirement with all the steps and control functions completely independent of operator intervention. The system is also designed specifically to meet the demands for maximum throughput and high yield for metal deposition and to provide a high level of flexibility in process control for other materials.

FIGURE 1.1-1 MOCKUP OF MODEL 4410 DELTA CATHODE PRODUCTION SPUTTERING SYSTEM

The Model 4410 System, as shown in Figure 1.1-1, utilizes a fast cycle Load Lock, two stage Cryopump, or a turbomolecular pump, a 36.7 cfm mechanical rotary-vane pump, and full flood LN_2 Meissner Trap to maintain the process chamber at high vacuum and in a clean condition at all times.

The Model 4410 System employs up to three delta-shaped cathodes in DC Magnetron configuration, or up to three circular cathodes in either RF diode, RF or DC Magnetron in various configurations. Primarily, the delta-shaped cathode, as shown in Figure 1.1-2 is used in the Model 4410 System. The delta cathode eliminates the need for a large-area uniformity-shaping aperture, thus maximizing target utilization and product throughput while maintaining batch uniformity.

FIGURE 1.1-2 TARGET SIDE OF DELTA CATHODE

1.2 SYSTEM PHYSICAL DESCRIPTION

The Perkin-Elmer Model 4410 Production Sputtering System is specifically designed for high rate deposition of metals and metal alloys on flat substrates. The resulting films range in thickness from a few Ångstroms up to a fraction of a millimeter. The system reflects an advanced design concept based on a high capacity Load Lock that permits wafer loading without breaking vacuum in the process chamber.

Figures 1.2-1, 1.2-2, and 1.2-3 are diagrams which show the dimensions of the Model 4410 System. The processing chamber is comprised of a 28-inch-diameter (OD) x 12-inch-high stainless steel cylinder which is flanged at both ends with fully captured O-ring seals. The chamber is provided with a viewing port on the chamber periphery for observation during loading or sputtering processes. The top plate is formed of stainless steel with provisions for mounting three delta-shaped cathode or adaptor assemblies (see Figure 1.2-4). The top plate also supports the RF matching network enclosure, hoist bracket, and sputtering control panel.

The units, shown in Figures 1.2-1, 1.2-2, and 1.2-3 encompass the basic Model 4410 System. Detailed description of each unit and its function is provided in Chapter 3.

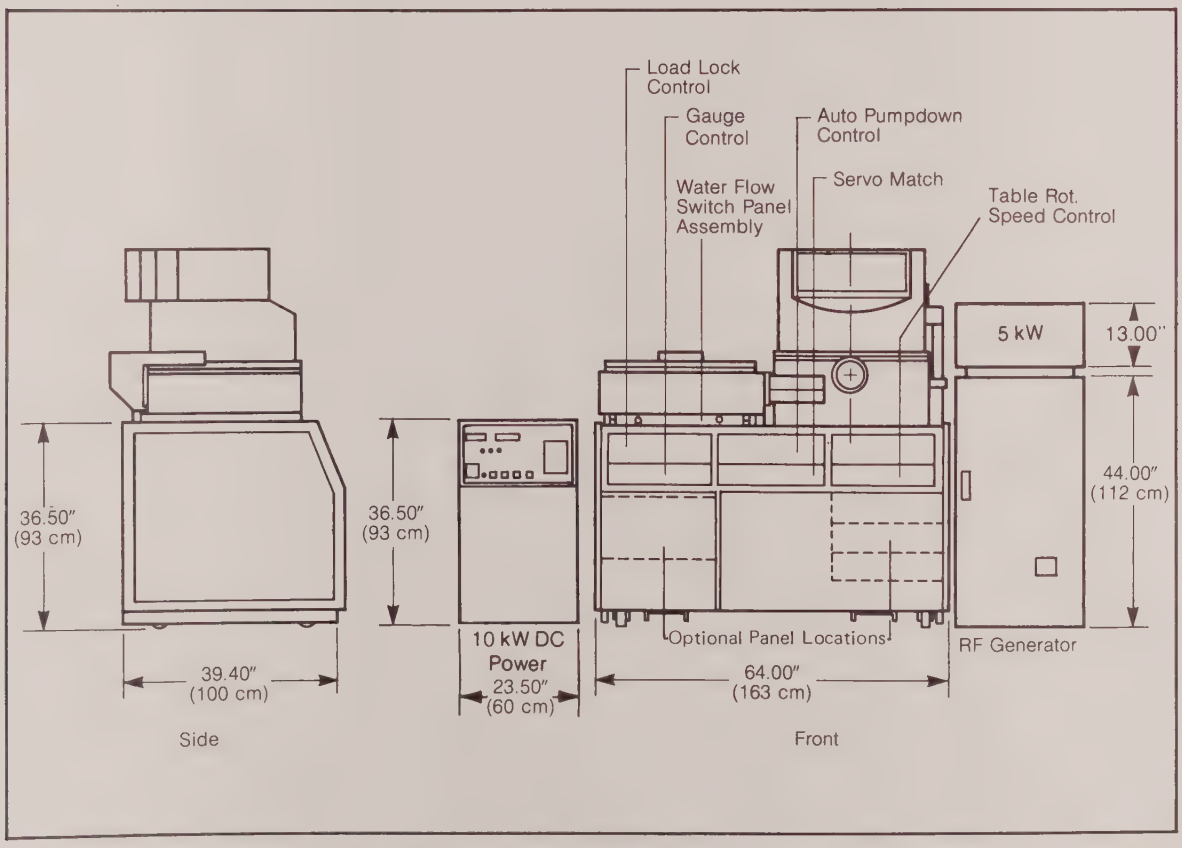

FIGURE 1.2-1 MODEL 4410 DIMENSIONS—FRONT AND SIDE VIEW

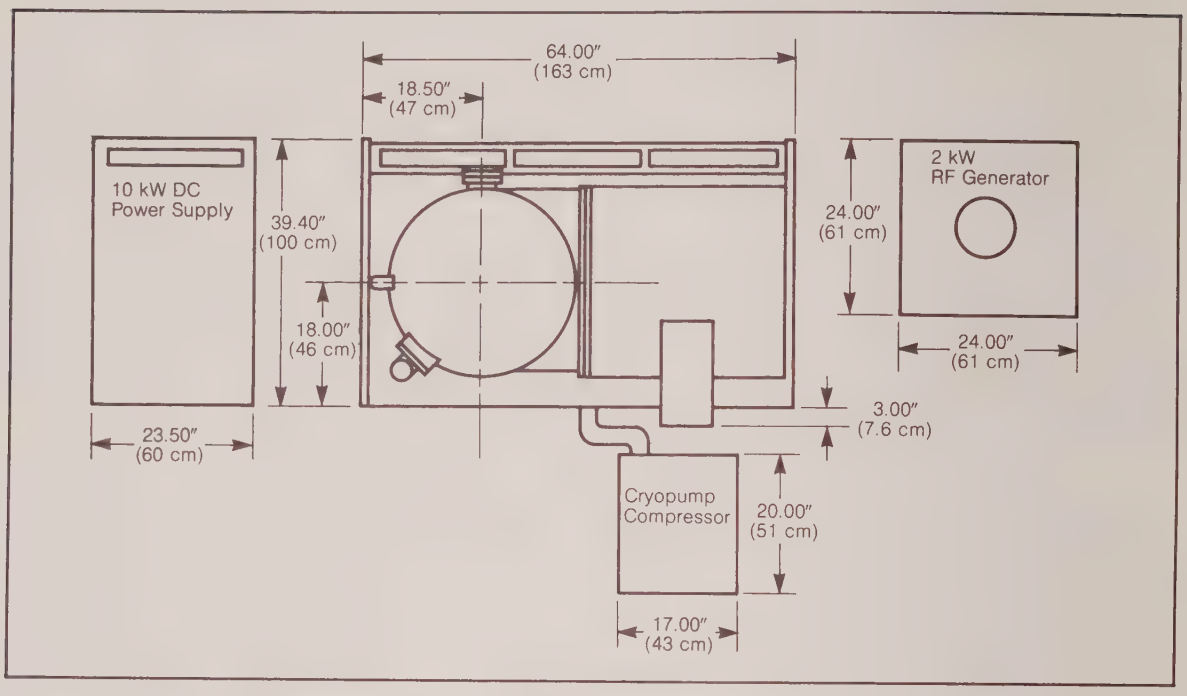

FIGURE 1.2-2 MODEL 4410 DIMENSIONS—TOP

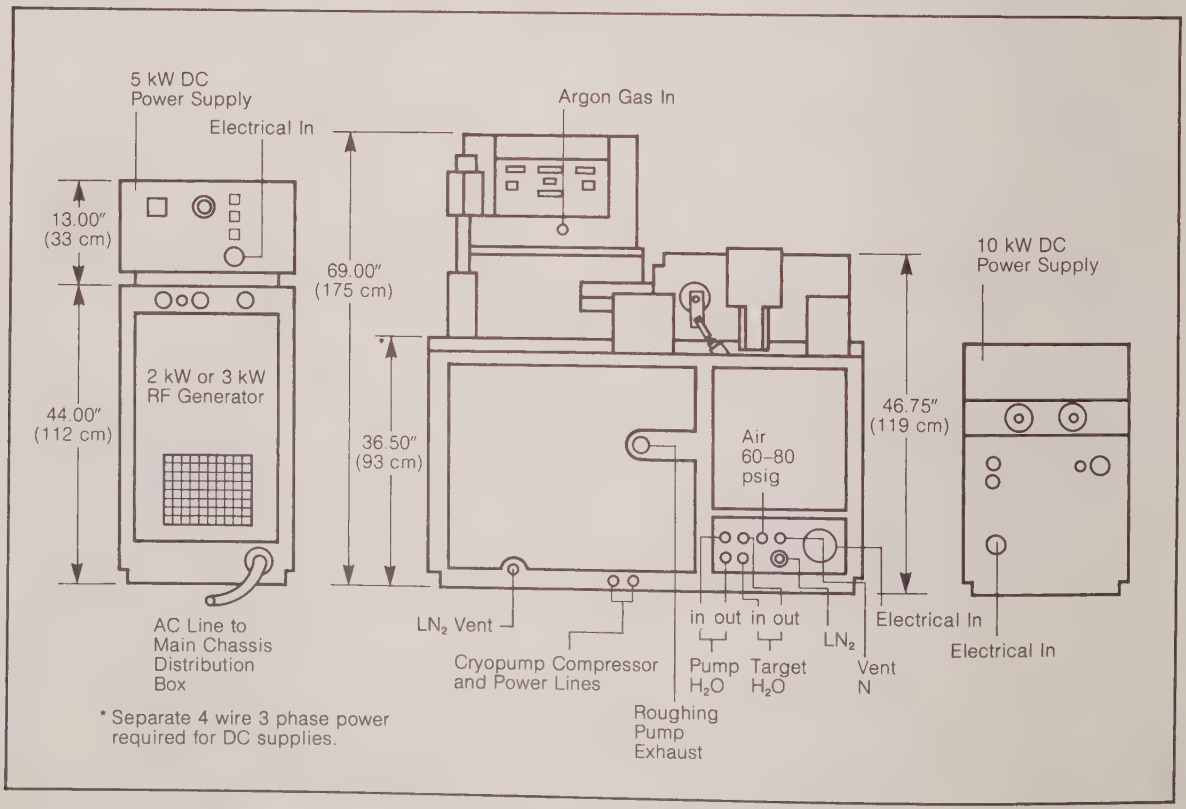

FIGURE 1.2-3 MODEL 4410 DIMENSIONS—BACK VIEW

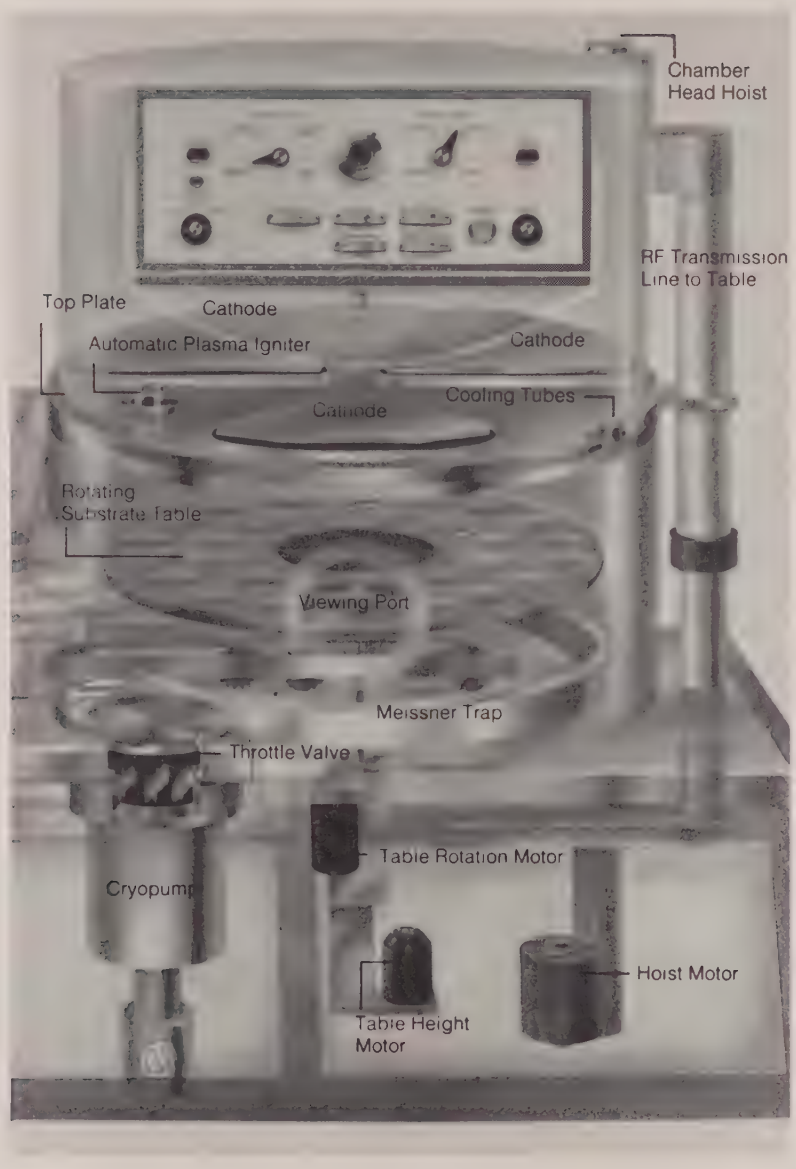

FIGURE 1.2-4 PROCESS CHAMBER AND CATHODE LAYOUT

1.3 POWER SUPPLIES

During processing, power is provided by a 1, 2, or 3 kW RF generator, tuned to 13.56 MH_z, or a 5 or 10 kW DC Magnetron power supply. Both the RF generator and the DC power supply are mounted in separate cabinets which can be remoted from the main console.

1.4 FUNCTIONAL DESCRIPTION

The Model 4410 System sequentially deposits up to three different materials onto substrates, thus obtaining sandwich-structured films such as multi-layer optical interference filters or semiconductor devices. The system can also be used for sputter-etching, primarily for pre-cleaning or degreasing substrates prior to deposition.

Before loading the system, the operator must ensure that all pre-set conditions necessary to initial start-up have been observed. These conditions are described in detail in Chapter 4. The automatic pumpdown of the system is initiated after placing a substrate pallet onto the Load Lock elevator and activating both lock door switches simultaneously (see Figures 1.4-1 and 1.4-2). Once the switches are actuated and held closed, the elevator supporting the substrate pallet is automatically lowered, the Load Lock lid is closed, and pumpdown started.

FIGURE 1.4-1 LOADING THE LOAD LOCK ELEVATOR

The roughing pump will bring the Load Lock from atmosphere to pre-set vacuum and the lock isolation valve will open into the process chamber. After the pallet is transported on the jam-free pallet transfer system into the process chamber, the anode substrate table is elevated into position, the carrier comes out and the interchamber valve door closes. The chamber is then backfilled with argon and proper pressure achieved in preparation for processing.

Following completion of processing, the loading procedure is reversed for removal of the substrate pallet.

FIGURE 1.4-2 LOAD LOCK CHAMBER WITH PALLET

1.4.1 Design Objectives

The Perkin-Elmer Model 4410 was designed to produce a system with the following objectives:

1. Perform high-rate Delta DC Magnetron sputtering. Aluminum and aluminum alloys can be sputter deposited at rates of up to 200 Å/kW/min. with loads of thirty 3-inch or fourteen 4-inch wafers.

2. Allow optimum use of the processing equipment for maximum wafer efficiency and production rate.

3. Provide maximum versatility to process a variety of products and apply the proper sputter mode for each application, such as sputter deposit, up to 10% RF bias sputter, DC bias sputter, sputter etch to 1 kW, RF Magnetron, RF diode, and DC Delta Magnetron.

4. To provide and ensure high vacuum for contamination-free conditions for critical deposition processes such as aluminum alloys and platinum.

5. To facilitate wafer loading and unloading by providing tweezer grooves for the operator.

6. To minimize and facilitate maintenance by providing removable deposition shields to permit easy system cleaning.

7. To provide a fail-safe system with waterflow switches which automatically shuts down the appropriate system component if the cooling system fails.

8. Designed for greater safety, providing two-button operation to initiate pumpdown and load sequence.

9. Allow for physical growth and configuration changes to accommodate future production demands.

Perkin-Elmer has achieved these objectives with the Model 4410 design which provides the desired flexibility required for a specific process characterization as well as high volume fabrication of processed products.

1.4.2 The Sputtering Process

Sputtering is a coating process which involves the transportation of almost any material from a source called the target, to a substrate of almost any other material. The ejection of the source material is accomplished by the bombardment of the surface of the target with gas ions accelerated by a high voltage. Particles of atomic dimensions are ejected from the target as a result of momentum transfer between incident ions and the target. The target-ejected particles traverse the vacuum chamber under viscous or transitional flow conditions from the extended target surface. The particles are subsequently deposited on the substrates as a thin film. In the sputtering process, the momentum of the bombarding particles is more important than the energy. For example, a hydrogen or helium ion accelerated to 3000 eV will cause very little sputtering compared to an ion of argon (which is chemically inert) with the same 3,000 eV energy. This results because at the same energy, the much lighter hydrogen or helium ion has much less momentum than a more massive argon ion.

The sputtered atoms travel until they strike a substrate, where they are deposited to form the desired layer. As individual atoms they can be chemically active and can form compounds with the ions and atoms of some of the bombarding gases. For this reason inert argon gas is used for bombarding. Where desired, a reactive gas may be intentionally added to argon so that the deposit is a chemical compound, which may be different from the target material. When argon ions strike the target, their electrical charge is neutralized and they return to the process as atoms. Secondary electrons are generated during the ejection of target atoms and these electrons serve to sustain the glow discharge by ionizing neutral argon atoms. Some argon may be also reflected from the target or energetic neutral atoms which can bury themselves in the substrate film.

If the target is dielectric, the bombardment process results in a positive charge on the target surface. This charge may grow to the point where the bombarding ions are repelled and the sputtering process stops.

To continue the process, the polarity of the influencing field must be reversed to attract enough electrons from the discharge to eliminate the surface charge. This periodic reversal of polarity is accomplished automatically by applying RF voltage to the target assembly (hence the term "RF sputtering"). Of special

interest here is the diode rectifier-like behavior of the target and discharge system. This is caused by the vast difference in mobilities of ions and electrons. The latter being so much faster, are attracted in much greater numbers to the target during the positive half cycle of the RF voltage than the heavy ions during the negative half cycle. The result or net effect is a self-induced negative DC voltage (bias) on the target.

General system theory of operation for the Model 4410 sputtering System is as follows: The mechanical pump initially brings the chamber pressure down to about 200 microns. At this point the high vacuum pump is used to attain and maintain a pressure of less than 5×10^{-7} Torr. Sputtering takes place in the process chamber after it is backfilled with argon to the proper pressure which is normally in the range of 1 to 20 microns.

The types of sputtering processes associated with the Model 4410 System are the (1) RF Sputter Deposition (2) DC Sputter Deposition (3) Sputter Etching; and (4) RF Bias Sputtering. Each process is designed to perform a particular function. The RF or DC deposit, for example, is used for depositing thin layers of material on a substrate while RF sputter etching is employed mainly for removing very thin layers from the substrate surface. Bias sputtering is a combination of deposit sputtering and simultaneous sputter etching brought about by splitting the applied RF power between the cathode and substrate table.

1.4.2.1 Sputter Deposition RF Diode

After acquiring the proper vacuum, argon is flowed into the chamber and caused to become ionized by the RF power applied between the cathode and ground with plasma initiation by ejection of electrons from an automatic igniter. When a negative potential is applied to the cathode, the ions are attracted to the negative cathode and impinge with momentum determined by the potential applied and the mass of the ion. The ion momentum is transferred to the cathode material lattice structure and can cause surface cathode atoms to be ejected (sputtered). These "sputtered" atoms travel across the gap between the cathode and the substrate table (or pallet) and deposit on the substrates lying on the substrate table.

1.4.2.2 Sputter Deposition RF Magnetron

RF Magnetron operation is almost identical to normal diode sputtering. It is used where the addition of the magnetic field deflects the secondary electrons produced in the sputtering process away from the substrates. Use of the RF Magnetron permits deposition of materials on substrates that require lower temperature than those which can be obtained conveniently with normal diode sputtering.

1.4.2.3 Sputter Deposition DC Magnetron

Magnetron cathodes enhance the plasma density and increase the sputtering rate, by trapping the electrons in an electromagnetic "bottle." This bottle is formed when the magnetic field lines exit and enter the target face and when the locus of maximum transverse magnetic field forms a closed figure. Because the currents involved are very large, a separate positively biased anode is used to collect the electrons.

1.4.2.4 Bias Sputtering

Bias sputtering is a combination of RF deposit and sputter etching. RF power is applied to the target, but a small amount of RF power is also applied to the substrate table. Consequently, substrates are also bombarded by ions, but to a lesser degree than the target. In many cases, this technique yields higher quality films than RF sputtering with grounded substrates. Bias sputtering controls the crystal structure and tends to resputter trapped argon from the growing film during deposition, improving stoichiometry, and step coverage and adjusting resistivity and film stress to desired values.

1.4.2.5 Sputter Etching

Sputter etching is essentially the reverse of RF sputter deposition. It is used for cleaning the substrate. In this case, the substrate table (with the substrates on it) is made negative with respect to the shutter. The ionized gas molecules bombard the substrate causing it to sputter atoms which are collected by the shutter. The shutter is imposed in front of the cathode to prevent the sputtered material from the pallet and substrate from contaminating the cathode.

1.4.2.6 Reactive Sputtering

Some metals such as nitrides and oxides are best deposited by reactive sputtering in which the target is the parent metal and a small amount of nitrogen or oxygen is added to the argon discharge. Ionized gases are generally highly reactive; therefore, a film deposited in a mixture of argon and oxygen will, in many cases, be an oxide rather than the parent metal. The amount of oxygen or nitrogen or other active gas to be added to the argon depends on the metal being deposited, the deposition rate, etc., and has to be determined experimentally.

Some nitrides and oxides such as SiO_2 are best deposited in argon enriched by oxygen. Without this oxygen, using a SiO_2 target will often lead to brownish films resulting from depletion of the oxygen (the deposited film has a small percentage of SiO.)

CHAPTER 2

INSTALLATION

WARNING

THE INITIAL REASSEMBLY AND INSTALLATION OF THE MODEL 4410 SYSTEM IS THE JOINT RESPONSIBILITY OF THE CUSTOMER AND PERKIN-ELMER, PLASMA PRODUCTS DIVISION. THE INSTALLATION SITE MUST BE PREPARED BY THE CUSTOMER (ALL UTILITIES SUCH AS GASES, WATER, AND POWER MUST BE INSTALLED AND READY FOR CONNECTION) BEFORE THE ARRIVAL OF PERKIN-ELMER FIELD REPRESENTATIVE. CONNECTION OF UTILITIES TO THE 4410 SYSTEM IS CUSTOMER RESPONSIBILITY AND IS TO BE DONE WHEN PERKIN-ELMER REPRESENTATIVE INSTALLS THE SYSTEM. INITIAL SYSTEM POWER-TURN-ON MUST BE CONDUCTED BY PERKIN-ELMER REPRESENTATIVE ONLY. FAILURE TO COMPLY WILL NULLIFY THE WARRANTY.

2.0 OVERVIEW

The Perkin-Elmer Model Ultek 4410 Delta Cathode Production Sputtering System is fully assembled and its mechanical, electrical, and pneumatic parts are aligned, adjusted, and tested prior to shipment. After Quality Control testing, the system is partially disassembled and crated for shipment.

This chapter describes the tasks required to reassemble, connect, and perform minor adjustments before contacting Perkin-Elmer Field Service for system start-up. These procedures are outlined for general situations. Individual interface considerations may change these procedures.

2.1 SYSTEM INSPECTION

Each system is carefully inspected both mechanically and electronically before shipment. The customer should inspect the crates when they arrive and release the carrier only after the inspection has been completed. The system should be unpacked with care and all packing cases or materials preserved until the contents have been carefully examined and compared with the shipping memorandum. The customer should inspect for physical damage and for signs which indicate the crates were dropped, impacted, or penetrated by other cartons, crates, or handling equipment. Also, he should examine the accellerometer mounted on the lower frame under the system cabinet.

If the system was damaged in transit, the customer should immediately notify the carrier and retain all damaged goods for inspection. The carrier should always be notified first, otherwise Perkin-Elmer will be unable to assist the client in recovering the amount of claim against the carrier.

2.2 ASSEMBLY

NOTE

BEFORE MOVING THE MODEL 4410 INTO A CLEAN ROOM, THE ENTIRE MACHINE SHOULD BE CLEANED ACCORDING TO THE CUSTOMER'S PROCEDURES FOR ENTRY INTO THE CLEAN ROOM. IN ADDITION, AFTER THE ASSEMBLY, POWER-TURN-ON MUST BE SUPERVISED AND CONDUCTED BY A PERKIN-ELMER FIELD REPRESENTATIVE ONLY.

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Normally only the compressor, the generator, the DC power supply, pallet, and the digital gauge control are shipped as separate units. The mechanical pump should be unbolted and raised from the frame by the rubber spacers located under the pump. The system must be leveled (using the top plate as reference) after it is completely assembled and placed in a permanent location convenient to the necessary utilities. To properly align the system, ensure it is level end-to-end and front to back. It should be noted that if the machine is not completely level, problems may be experienced during processing.

2.3 REQUIREMENTS

The following lists the preliminary requirements (by the customer) for the assembly and installation of the Model 4410 system.

1. Site Preparation—providing all utilities at the location where the system will be installed.
2. Crate Inspection—ensuring that the crated system was not dropped, stabbed by a fork lift, etc.
3. Uncrating—removing the Model 4410 System and associated parts from the crates.
4. Inventory—documentation, parts, and tools.
5. Inspection—ensuring that all parts of the system are intact and accounted for.
6. Assembly—reassembling the uncrated parts for test preparation.
7. Utilities connection—connecting the Model 4410 System to the power, air, LN_2, N_2, and Argon. Items 8, 9, 10 must be conducted by a Perkin-Elmer Field Representative.

UNDER PERKIN-ELMER SUPERVISION:

8. Power—applying power to the system for the first time.
9. System Checkout—ensuring that the system is operational.
10. Preparation for use.

2.4 SITE PREPARATION AND INSTALLATION

To achieve the optimum in the use of your sputtering system, and under the direction and guidance of Perkin-Elmer, Plasma Products Division, Field Service technicians, we recommend the following:

1. The customer is to provide a clean work area in accordance with Federal Standards, 209A (1), dated 30 May 76, "Clean Room and Work Station Requirements, Controlled Environment". This specifies a Class 100,000 microns, clean work area. This means, among other things, an area where no smoking or eating is allowed.
2. To provide sufficient space for the unit, and to ensure that the ambient temperature in the area is between 40° to 100°F (5° to 38°C). The unit should not be mounted flush against the wall or against the units placed at either end because normal maintenance and adjustments are done from all four sides.
3. To provide access to facility power, nitrogen, argon, air, and water lines.

TABLE 2.4-1

MODEL 4410 SYSTEM DIMENSIONS

	Width (Inches)	Length (Inches)	Height (Inches)
Main System	39.40 (100 cm)	64.00 (163 cm)	69.00 (175 cm)
Power Supplies			
1 kW (RF)	24.00 (61 cm)	24.00 (61 cm)	44.00 (112 cm)
2 kW (RF)	24.00 (61 cm)	24.00 (61 cm)	44.00 (112 cm)
3 kW (RF)	24.00 (61 cm)	24.00 (61 cm)	53.00 (135 cm)
5 kW (DC)	24.00 (61 cm)	24.00 (61 cm)	13.00 (33 cm)
10 kW (DC)	23.50 (60 cm)	39.40 (100 cm)	36.50 (93 cm)

DANGER

POWER CONNECTIONS

THE MODEL 4410 USES HIGH VOLTAGE THAT CAN BE FATAL IF CONTACTED. THE POWER SHOULD BE TURNED OFF AND ELECTRICAL CONNECTIONS MADE BY A QUALIFIED ELECTRICIAN.

NOTE

THE CONNECTIONS ARE MADE TO A TERMINAL BLOCK INSIDE THE POWER DISTRIBUTION BOX.

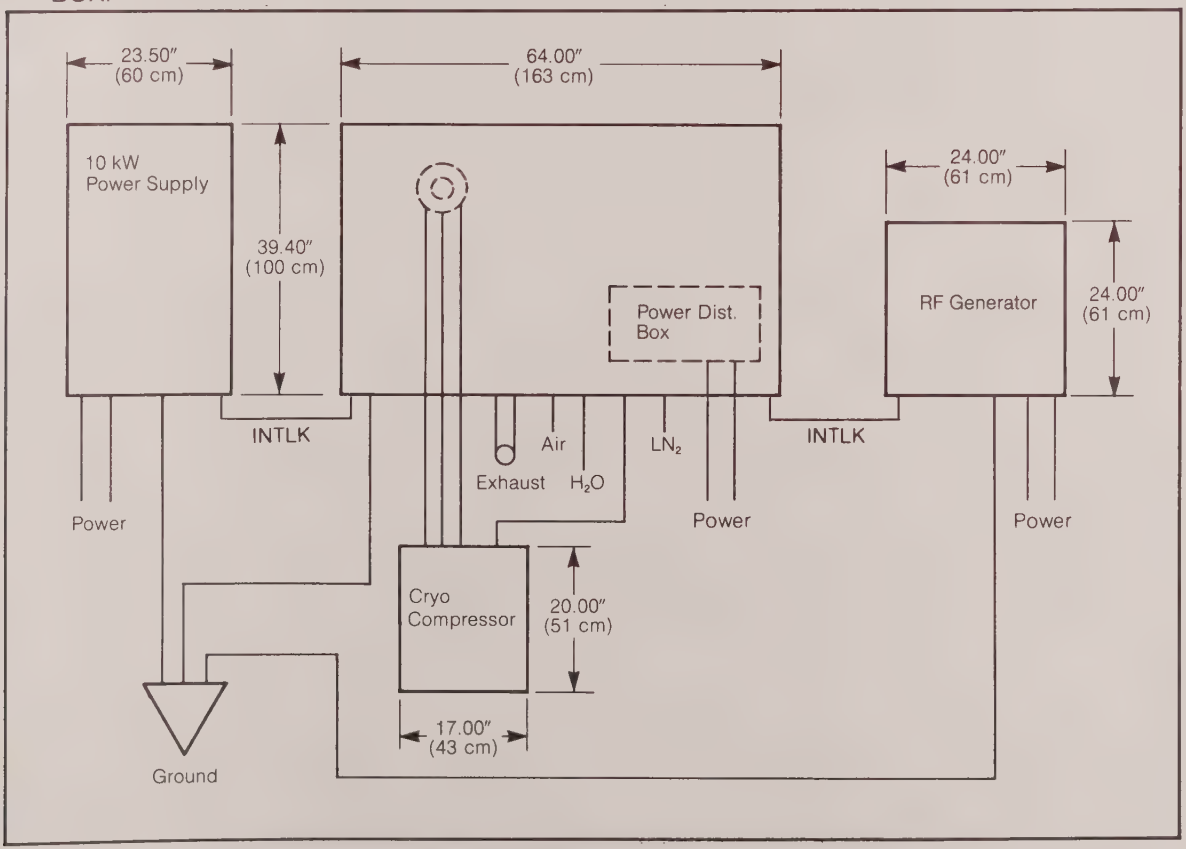


FIGURE 2.4-1 SITE PREPARATION BLOCK DIAGRAM

2.4.1 Facility Power Requirements

The customer is to provide 100 Ampere (Amp) service to the unit. However, for the 5kW RF generator, 100 Amp service is sufficient; but, with the 10 kW RF generator, 125 Amp service is required.

TABLE 2.4-2

POWER REQUIREMENTS

Vacuum System 100 Amp Service	208 V AC, 60 Hz/3 phase, 100 Amp. 5-wire system with separate neutral and ground lines. Grounding rod should be short and preferably in close proximity to the system. 230 V AC 60 Hz/4-wire systems are available on request. 380 V AC 50 Hz, 280 V AC, 60 Hz, or 200 V AC, 50 or 60 Hz are available.
2/3 kW RF Generator 100 Amp Service	208 V AC, 50/60 Hz/single phase, AC power for RF Generators derived from system power distribution box. Current usage is included in the vacuum system specification.
5kW DC Power Supply 100 Amp Service	208 V AC, 60 Hz/3-phase, 30 Amp. Other voltages available. A separate 4-wire (no neutral) AC line is required for all DC power supplies.
10 kW DC Power Supply 125 Amp Service	208 V AC, 60 Hz/3-phase, 60 Amp. Other voltages and 50 Hz systems are available. A separate 4-wire (no neutral) AC line is required for all DC power supplies. Separate service.

SAFETY FIRST, LAST, AND ALWAYS

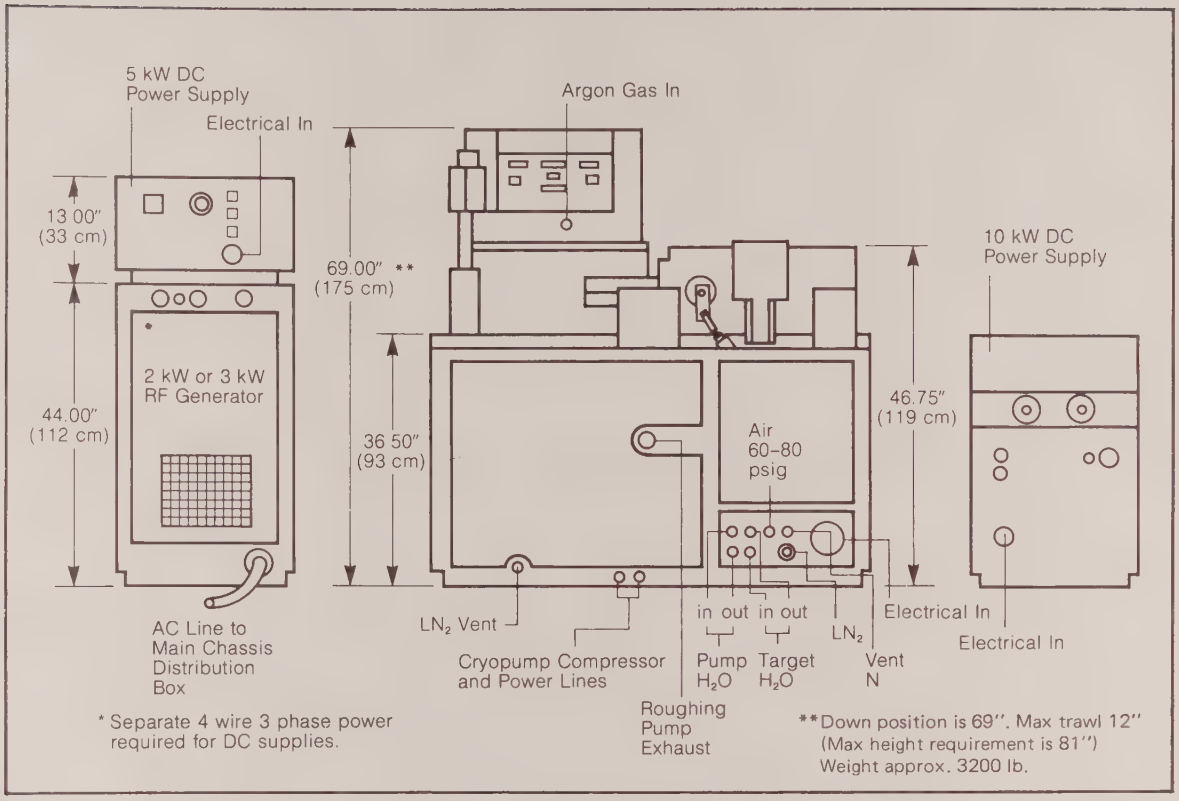


FIGURE 2.4-2 TYPICAL UTILITY CONNECTIONS

WARNING

THE SYSTEM SHOULD NEVER BE OPERATED WITHOUT AN ADEQUATE GROUNDING CONNECTION. IF EQUIPMENT IS MOVED, A NEW GROUNDING CONNECTION MUST BE ESTABLISHED BEFORE POWER IS TURNED ON.

AN OPERATOR'S TRAINING COURSE IS AVAILABLE
CALL (415) 967-2100

TABLE 2.4-3

MODEL 4410 SYSTEM UTILITIES SPECIFICATIONS

	Process Chamber	Vacuum System	2kW RF Generator	10kW DC Power Supply
Voltage	–	208V AC (1)	208V AC	208V AC (2)
Freq/Phase	–	50/60 Hz/3	50/60 Hz/Sing.	50/60 Hz/3
Amerage	–	60	(3)	60 (4)
Water	(5)	(6)	0.5gpm (7)	1.5gpm
Dry Nitrogen (N_2)	–	30 psig (8)	–	–
Argon	5-10 psig	–	–	–
Liquid Nitrogen (LN_2)	–	2L/hr (9)	–	–
Air	–	60-70 psig (10)	–	–

NOTES:

(1). Five-wire separate neutral and ground lines; grounding line should be short; grounding rod in proximity to system; 230V AC, 60 Hz, 4-wire systems available on request; 380V AC, 208V AC or 200V AC, 50 Hz available.
(2). Separate 4-wire (no neutral) AC lines required for all DC power supplies.
(3) AC power for all RF generators derived from system power distribution box; current usage included in vacuum system specifications.
(4). Thirty amps for 5kW DC power supply; separate AC line.
(5). Substrate table cooling water in parallel with RF matching network; add 0.5 gpm for the water-cooled top plate and process chamber.
(6). Water consumption @ 60-80 psig is minimum 0.4 pgm for cyropumped systems and 0.12 gpm for turbopumped systems.
(7). Water consumption should be minimum 0.5 for table and RF matching network @ 60-80 psig and 1-2 gpm for cathode cooling. Inlet water temperature should be 60°F or cooler.
(8). Full purge Control (Water lines and Meissner trap) and venting of Load Lock and process chamber.
(9). Full flood Meissner trap usage @ 10-25 psig (25 psi max.).
(10). For valve operation-low flow rate.

2.4.2 Auxiliary Line Connections

1. **Argon.** To avoid contamination of the 99.999% purity of the argon gas, stainless steel flex-line tubing shall be used. Also, an in-line oxygen filter of the cartridge type should be installed to eliminate any water vapor/condensation. The best second choice is high grade copper tubing in conjunction with an oxygen filter of the cartridge type to trap all vapor, moisture and condensation. The argon pressure should be regulated to a range of 5 to 10 pounds per square inch gauge (psig).

2. **Air.** Compressed air free from oil and water, or nitrogen may be used for the pneumatic valve operation. Both the air and nitrogen should be at 60 to 80 psig. Since nitrogen is also used as load lock and chamber gas, a separate regulator for supplying nitrogen vent of no more than 30 psig must be used.

3. **Liquid nitrogen.** The liquid nitrogen (LN_2) connector must be regulated at 10 to 15 psig, but must not exceed 25 psig. Consumption for the full flood Meissner Trap is 2 liters per hour (2L/hr.).

4. **Water.** WATER FLOW IS ABSOLUTELY NECESSARY TO PREVENT TOTAL SYSTEM FAILURE AND SHUTDOWN. IF, FOR ANY REASON, THE WATER FLOW STOPS, THE WARRANTY IS NULL AND VOID. The inlet water pressure should be 60 to 80 psig and the outlet pressure 9 to 20 psig. This ensures that the pressure difference between IN and OUT lines do not fall below 40 psig. The water temperature shall be between 40° to 60°F (+2°-17°C). A separate valve for each IN and OUT line must be provided by the customer. The output of the water flow shall be 15 gallons per minute (gpm), which provides 1.5 gpm for DC targets, and 1 gpm for RF targets. Total flow requirements for a typical 4410 installation range from a low of 2 to 4 gpm. To prevent system damage, the water used in the system should cause no mineral deposits; should be essentially free of silicon dioxide (SiO_2), and be of relatively low electrical conductivity. However, with proper filteration and cooling, the system will operate satisfactorily with ordinary high quality tap water at 60°F (17°C) or cooler. In general, the cooling water supplied to the system should have a restivity of between 25,000 and 75,000 ohm-cm, and pH factor of 6.8 to 8.4. (Note: pH^{-7} is considered "neutral" water.)

5. **Exhaust.** In the event of total loss of power to the unit, the mechanical pump will exhaust to the immediate area. Therefore, the customer has the responsibility to provide an exhaust from the mechanical pump to the outside of the building. You are urged to contact your Perkin-Elmer Plasma Products Division, field service technician if you have any questions regarding the exhaust system.

2.5 PREPARATION FOR OPERATION

The preparation for operation consists of a visual and power checkout procedure. The procedure entails the following:

1. Verify that all tubing, connectors, and plugs are properly installed.
2. Verify that all circuit breakers and power switches are set to off position.
3. Check the oil level in the mechanical pump. The oil level should be just above the lower line in the sight glass.
4. Verify that the processing chamber and load lock doors are closed and that every ON/OFF toggle switch on each control panel is set to the OFF position.
5. Ensure that the RF generator and the heater power is off; foreline valve closed; process chamber and load lock vent valves closed; and roughing and high vacuum valves are closed.

After these pre-operation procedures have been completed, DO NOT proceed with "Power-Turn-On" procedure.

Power-Turn-On, initial system checkout, and preparation for operation is to be conducted under the supervision of a Perkin-Elmer representative.

CHAPTER 3

SYSTEM ENGINEER'S GUIDE

3.0 INTRODUCTION

The System Engineer has the responsibility of configuring, maintaining, and ensuring that the Model 4410 Delta Cathode Sputtering System functions properly. He must be thoroughly familiar with the operation and maintenance of the system and be able to define and correct errors whenever they occur. The procedures to be performed by the System Engineer include the adjusting of parameters that control the sputtering process, selection of operating modes, cleaning the system, and regeneration of the cryopump when necessary, as well as providing periodic maintenance.

This chapter provides detailed physical and functional descriptions and operating procedures for the following major components of the Model 4410 System:

1. Power Supplies
2. Pumping System Assembly and Controls
3. Load Lock System and Controls
4. Process Chamber, Sputter Head Module, and Controls
5. System Instrumentation and Options

3.1 POWER SUPPLIES

The following power supplies are provided as standard features with the Model 4410 System:

1. RF Generator (1, 2, or 3 kW)
2. DC Magnetron (5 or 10kW)

Although both RF and DC power supplies can be provided with the Model 4410 system, the inclusion of either one is dictated by user needs. Each 4410 system has a choice of 1, 2, or 3 kW RF generator unit when RF capability is included, and a 5 or 10 kW DC power supply when DC magnetron capability is needed. Substrate etching prior to deposition requires an RF power supply.

3.1.1 RF Generator

WARNING

THE OPERATING VOLTAGES INSIDE THE RF GENERATOR ARE LETHAL. PERSONNEL OPERATING THE RF GENERATOR OR MAKING ADJUSTMENTS SHOULD BE QUALIFIED ELECTRONIC TECHNICIANS AND HAVE A GOOD UNDERSTANDING OF ELECTRONIC MAINTENANCE AND RF.

The RF power generator consists of a crystal-controlled exciter section, a one-stage linear power amplifier, and a power supply capable of delivering all the necessary operating voltages (see Figure 3.1-1). The power generator delivers its rated output for continuous-duty operation (refer to Appendix A).

Complete overload protection, remote operation, and casters are standard. Harmonic and other spurious radiation is reduced in accordance with FCC regulations and OSHA standards.

FIGURE 3.1-1 RF POWER GENERATOR

The power tube develops high temperatures during operation, therefore the generator should be situated where it can be properly cooled. The equipment should be placed far enough away from any wall, furniture, or surface to allow for an adequate flow of cool air through the rear vent. Objects should not be placed on the ventilating grill on top of the generator.

3.1.1.1 Safety Interlock Switches

Safety interlock switches are provided as a standard feature incorporated into all systems. They ensure operator and system protection during RF and DC sputtering modes.

If any of the following interlocks are not properly activated the RF and DC power will not turn on.

1. Water Flow Switches
   Adequate water flow for cooling must be provided.

2. Sputter Module Cover Switches
   All covers must be in place on the sputter module.
3. RF Generator Doors and DC Power Supply Cover Panels.
   Both front and rear doors must be in place and closed on the RF generator, and side panels in place on the DC power supply.
4. RF Power Supply Power
   The RF Power Supply main power circuit breaker must be on.
5. Gas Mode
   The GAS mode must be ON to supply gas to the chamber.

3.1.1.2 Specifications for RF Generators

Operating Frequency	13.56 MHz
Frequency Stability	±2 kHz
Output Power	1000W, 2000W, or 3000W
Output Impedance	52 ohm. The standing wave ratio must not exceed 3:1 (reflected power not to exceed 25%)
Exciter	Crystal-controlled, 6.78 MHz oscillator with internal buffer/doubler.

3.1.1.3 Connection to the RF Generator

WARNING

THE POWER-ON PROCEDURE SHOULD BE CONDUCTED UNDER THE SUPERVISION OF A PERKIN-ELMER REPRESENTATIVE.

The RF generator should be placed near a grounding bus serving the laboratory. If a separate ground bus is in the laboratory, the RF generator chassis must be connected to the ground bus using a solid copper strap (silver plated if possible).

WARNING

NEVER OPERATE WITHOUT ADEQUATE GROUNDING CONNECTION. IF EQUIPMENT IS MOVED, MAKE SURE ALL NEW GROUNDING CONNECTIONS ARE ADEQUATE BEFORE TURNING POWER ON.

The control cable is installed between the sputtering module and the RF power generator.

CAUTION

THE OPERATING VOLTAGES INSIDE THE GENERATOR ARE LETHAL. DO NOT OPERATE GENERATOR WITH ANY OF ITS DOORS OR PANELS REMOVED.

When the circuit breaker on the RF generator is turned on, the green pilot light above the breaker on the front of the door panel of the cabinet will be illuminated and the cooling fan in the power supply cabinet will begin operating.

After the main breaker on the RF generator is turned on, the following procedure should be observed and adhered to.

IMPORTANT: Prior to applying significant power, turn the POWER ADJUST control on the control panel of the sputtering module fully counterclockwise (minimum power setting). Make sure the unit is under vacuum, at least from a roughing pump.

1. The operator must wait 90 seconds for the tubes to warm up.
2. After the initial 90-second wait, the RF ON button located on the sputter head may then be pushed.

Push the POWER ON/OFF button once. (If the button does not light up, push it a second time). The button should light immediately, indicating that high voltage for the power generator's output tubes was turned on. If the button does not illuminate, check the interlock circuit as described in Section 3.1.1.1.

3.1.1.4 Operating Cautions

Before turning the generator off, a 5-minute operation with the RF OFF should be allowed to cool the power tubes and prolong their life.

The RF generator should not be operated with any of its doors and panels removed. Perkin-Elmer PPD will not assume any liability for damage to the unit or harm to personnel if the interlocks are defeated. Before initial operation of the generator, the RF output should be connected to the sputter head or a dummy load. All covers and doors must be securely in place for safe operation. The interlocks should not be defeated—they ensure operator safety.

3.1.2 DC Magnetron Power Supply

Perkin-Elmer provides two separate models of DC Magnetron power supply units—a 5 kW and a programmable 5 kW and 10 kW (see Figures 3.1-2 and 3.1-3).

3.1.2.1 5 kW DC Power Supply

The DC power supply is a nominal 5 kW 12 ampere DC maximum output supply (see Figure 3.1-2). Output voltage is adjustable by means of either a manual control or external DC input voltage. Input power information is provided in Section 3.1.2.2. Certain features are incorporated to provide versatility and control. In addition, interlock functions are provided to ensure protection to the sputter module and targets. The unit is self contained, voltage and current metered. All controls are located on the front panel.

3.1.2.2 Specifications For DC Magnetron

Input:	1. 208 Vac—230 Vac, 3-phase, 4-wire, 60 Hz. 200 Vac, 3-phase, 4-wire, 50 Hz. 380 Vac, 3-phase, 4-wire, 50 Hz. 2. Connector, Arrow/Hart #6535, 480V, 30 Amp. Mate, Arrow/Hart #6534.
Output:	1. Current: Maximum 12A. 2. Voltage: Open circuit approximately 800 VDC 3. Protected for short circuits and plasma discharges.
Metering:	Voltage 0–1000 VDC. Current 0–15 Amp

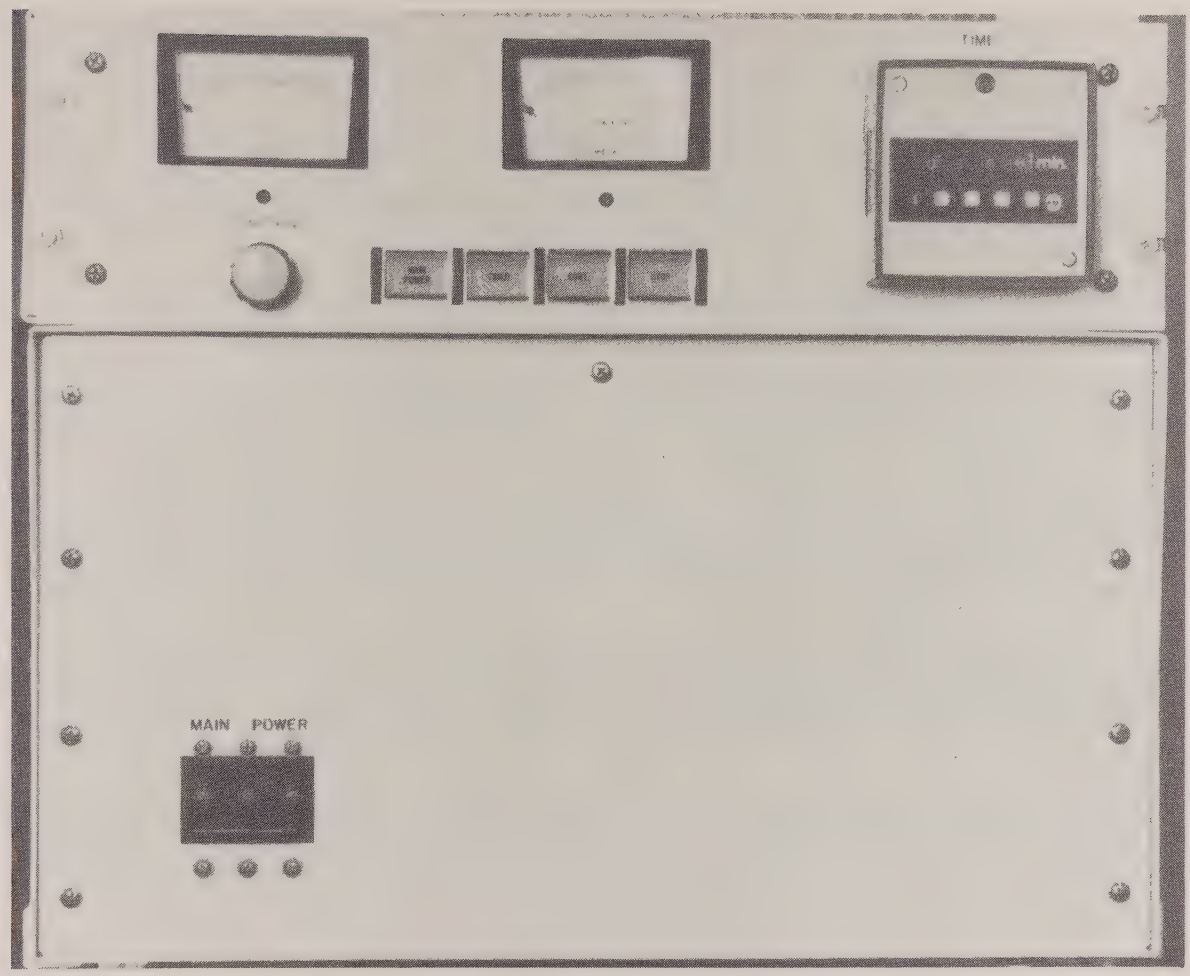


FIGURE 3.1-2 DC POWER SUPPLY

3.1.2.3 DC Magnetron Operation

Figure 3.1-2 shows the front panel of the DC Magnetron power supply. Refer to this figure during the following operating procedure.

NOTE: A system interlock circuit connects to the supply via connector J.

WARNING

THE OUTPUT OF THIS POWER SUPPLY IS POTENTIALLY LETHAL AND EXTREME CARE MUST BE EXERCISED TO AVOID CONTACT WITH THE SUPPLY OUTPUT WHEN IN OPERATION.

1. After checking that the power supply is correctly connected to a magnetron sputtering cathode and no short circuits exist, set the digital clock timer to a predetermined time, and turn on the circuit breaker on the DC Magnetron supply.
2. Set the system argon pressure to 5 microns.
3. Rotate the power control knob fully counterclockwise.

4. Set the desired deposition time by depressing the blue button on the timer and setting the time with the white buttons.
5. Check that the sputter system shutter is closed in front of the magnetron sputtering cathode.

WARNING

BEFORE OPERATING THE DC MAGNETRON BE SURE ADEQUATE WATER COOLING IS PROVIDED. WATER FLOW OF 1.5 GPM (5 LITERS/MIN) IS REQUIRED.

6. Depress the switch marked CONTINUOUS.
   At this time the plasma should ignite. If it does not, increase the pressure to 8 or 10 microns.

NOTE: The voltage and current may be very erratic as the target surface cleans up.

7. Operate the DC Magnetron until stable voltage and current indication are achieved.
8. Gradually increase the power by rotating the current control knob clockwise until the desired power level is achieved.
9. Simultaneously open the shutter and depress the TIMED switch.
10. The power supply will shut off when the timer reaches zero.

3.1.3 Programmable DC Magnetron Supply (5 or 10 kW)

The design concept of the 5 and 10kW DC Magnetron supplies is to provide a constant power into the load impedance connected across the output terminals.

The programmable DC Magnetron power supply as shown in Figure 3.1-3 regulates its output power to a constant volt-amp (VA) product as programmed into the unit by either the manually operated control potentiometer located on the front panel or by use of a remote control through a programming voltage through the connector located on the control box rear panel, J1.

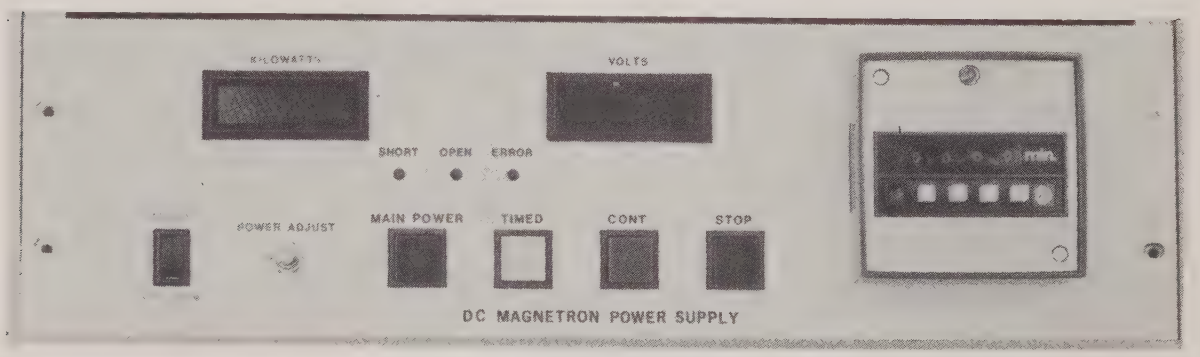


FIGURE 3.1-3 PROGRAMMABLE 5 kW OR 10 kW POWER CONTROL PANEL

The external input (J1) is selected by the PROGRAM/MANUAL rocker switch located on the front panel of the control box. The system is precisely calibrated such that the input voltage (DC) corresponds to the output VA product: Millivolts in equals Watts out.

When feeding a DC signal into J1, the control signal input should never be driven in excess of 5.2 VDC for the 5 kW unit or 10.4 VDC for the 10 kW unit. The potentiometer on the front panel limits the DC

input to approximately these same values, and corresponds to respective output power levels of 5.2 kW and 10.4 kW.

The programmable DC power supplies were designed primarily to provide power to the Model 4410 delta magnetron cathode. This delta source on the Model 4410 System requires a 3-wire input which consists of two MS type connectors, one located physically above the other on the rear panel. A third wire appears as a "Grounding Stud."

The upper MS connection is the negative output terminal. The lower MS connection is the "RETURN," (this output common is also the common for the circuits comprising the entire control for the supply).

When the supply is in operation and properly connected to the delta magnetron head assembly, this RETURN, (the lower MS) resides at a positive potential of approx. 20–30 VDC above chassis potential.

The toggle switch labeled ELEVATE (for one position) and GROUND in the other position must be placed into the ELEVATE position when the delta cathode target is to be used and should not be switched to ground while the power supply is operating. (The GROUND position of the toggle switch is merely for testing or using the supply for 8-inch diameter round DC magnetron cathodes.)

NOTE: The Grounding Stud (near the switch) must be connected to the system sputter head with a large wire (low resistance) and as short in length as possible. Output currents to the sputter head flow through the grounding wire (strap) as well as the other two output cables (hence, the 3rd terminal of the above mentioned 3-terminal system).

The capability of the output circuit to "elevate" above chassis ground potentials while allowing the control box chassis to remain at system chassis ground potential is accomplished by the utilization of optically coupled isolators between the control box and the output circuits.

3.1.3.1 Controls and Indicators

Three light-emitting diodes are located in the front panel control for reading out the conditions appearing at the output terminals of the supply. They are the following:

1. SHORT (short circuit appearing across the output).
2. OPEN (open circuit appearing at the output).
3. ERROR (appearing anytime the output VA product does not/or cannot match the programmed level, either for manual or programmed inputs). This condition is further discussed in Section 3.1.3.2 below.

Potentiometers located upon both the main frame PC board and the PC board in the control box, must not be adjusted except by a Perkin-Elmer field service engineer. They are preadjusted at the factory and require no additional adjustment.

3.1.3.2 The ERROR Indicating LED

This detector measures the differential error between the VA product appearing into the plasma load and the linear input DC voltage used for providing the input programming DC level.

The error indicator may briefly light during the changing of programming levels. The indicator will glow steadily anytime the supply begins to current limit and/or voltage limit. These two conditions would occur when "plasma-impedance" changes to either too low or too high a value.

The design load value for 5 kW units is 30–70 ohms. This value is 20–70 ohms for 10 kW units with current limit set at 25 ohms.

The error detecting indicator will illuminate when the following conditions occur:

1. The error lamp will glow anytime the programming DC voltage is at or near zero.
2. The error lamp will remain lighted until the output VA product increases from around zero to approximately 80–100 Watts as read on the Wattmeter on the control panel.
3. The error lamp will also light anytime an arcing condition within the sputtering head occurs for an appreciable time (feedback loop recovery is approximately 1.0 second at a program level of 10 kW).

NOTE: Gas pressure should be adjusted so as to keep the plasma resistance around 40 ohms for the 5 kW supply and 30 ohms for the 10 kW supply if possible. This will allow 5 kW to exist when supply voltage is approximately 500 VDC, and 10 kW when the voltage is approximately 707 VDC. Refer to Table 3.1-1 for indication.

3.1.3.3 Operation of the Programmable DC Power Supply

After the system is set-up and ready for operation, the following procedure should be observed before operation of the DC magnetron power supply.

1. Turn power adjust potentiometer to zero power (fully counter-clockwise).
2. Turn main power circuit breaker ON (located on the main power supply chassis).
3. Program/manual rocker switch to "MANUAL".
4. Select a predetermined deposition time on timer.
5. Press the CONTINUOUS button (to turn DC power on) and slowly turn POWER ADJUST knob clockwise to desired power level. The power is read in kilowatts on the digital meter.

TABLE 3.1-1

COMPARISON OF LOAD RESISTANCE/POWER

OUTPUT POWER (kW)	OUTPUT VOLTAGE FOR LOAD RESISTANCE OF 50Ω	OUTPUT VOLTAGE FOR LOAD RESISTANCE OF 40Ω
10	707 V.	632 V.
9	670 V.	600 V.
8	632 V.	565 V.
7	591 V.	529 V.
6	547 V.	490 V.
5	500 V.	447 V.
4	447 V.	400 V.
3	387 V.	346 V.
2	316 V.	283 V.
1	223 V.	200 V.

Above is a quick reference for determining the approximate resistance presented by a Plasma as computed from observing output power in Watts versus output Voltage as read on the front panel meters.

Gas pressure is adjusted to produce the corresponding values above. Refer to Section 3.1.3.4 to calculate plasma impedance for various voltage/power conditions. Use the following formula (Ohm's Law):

$$R_{PLASMA} = \frac{E^2 \text{ (volts)}}{P \text{ (watts)}}$$

6. Open the shutter to the target position that is being used (SHUTTER POSITION switch is located on the front panel of sputtering module).
7. As soon as the shutter is fully open (and the shutter rotation light goes out), press the TIME button. This will then activate the deposition timer and when it times out the DC power will shut off automatically.
8. After the deposition is completed, always turn the POWER ADJUST knob back to zero power (fully counter-clockwise).

If a problem arises during deposition, the STOP button should be pushed to turn off the DC power. The digital volt meter on the front panel of the DC control gauge indicates target bias voltage.

NOTE

FEEDBACK LOOP RECOVERY IS APPROXIMATELY 1 SECOND AT A PROGRAM LEVEL OF 10 kW.

3.1.3.4 Determining the Load Resistance Range

The 5 kW DC Magnetron Supply will develop its rated maximum power only when that load resistance presented to the supply is within the range of 30 Ohms (minimum resistance) and 70 Ohms (maximum resistance). The resistance range becomes 25 Ohms and 70 Ohms respectively for the 10 kW DC Magnetron Supply.

This load resistance range is a variable during system operation and is a function of such variables as gas pressure and DC power.

In order to determine whether or not the correct load resistance is provided by the sputtering system and presented to the DC supply output terminals, the following formula applies:

$$R = \frac{E^2}{P}$$

Where R is resistance of the plasma, E^2 is the voltage squared (E as read from the front panel meter) and P is power read from the front panel meter.

Further example: If power level reads 10 kW and voltage reads 836.6 VDC then the Plasma R = 70 Ohms (the upper R limit).

If power level reads 10 kW and voltage reads 500 VDC then the Plasma R = 25 Ohms (lower limit).

Note: Solving for unknown E if R and P are known:

$$E = \sqrt{PR}$$

Caution: Plasma R decreases with an increase of input power.
Plasma R decreases with an increase of Gas Pressure.

3.2 PUMPING SYSTEM ASSEMBLIES

The Model 4410 pumping system is designed for high gas handling capacity, fast pumpdown, and vacuum cleanliness. The pumping system described in this chapter consists of the pump package, instrumentation, and power distribution panel. The materials selected such as stainless steel, aluminum, copper, glass, and ceramic are compatible with good high vacuum practices. Where elastomer seals are required for convenience, only low vapor pressure fluorocarbon (Viton) materials are used and the recessed design of the seals precludes the possibility of plasma interaction with the sealing material. All systems include a 36.7cfm mechanical pump for roughing the Load Lock and backing or regenerating the high vacuum pump. In addition all systems are equipped with a high vacuum valve which has a 7½-inch (6-inch ASA) ID. This valve permits isolation of the high vacuum pump during maintenance periods for the process chamber. The Model 4410 system is available with either a closed-cycle helium cryopump or turbomolecular pump. In addition, the system is equipped with a full-flood Meissner trap in the chamber to maximize water vapor pumping capability even when the high vacuum pump is fully throttled during the sputtering process. Most 4410 systems are equipped with a cryopump as described in the following section. Systems may however be supplied with turbomolecular pumps for special applications. Venetian blind throttle valves are standard on cryopump equipped systems.

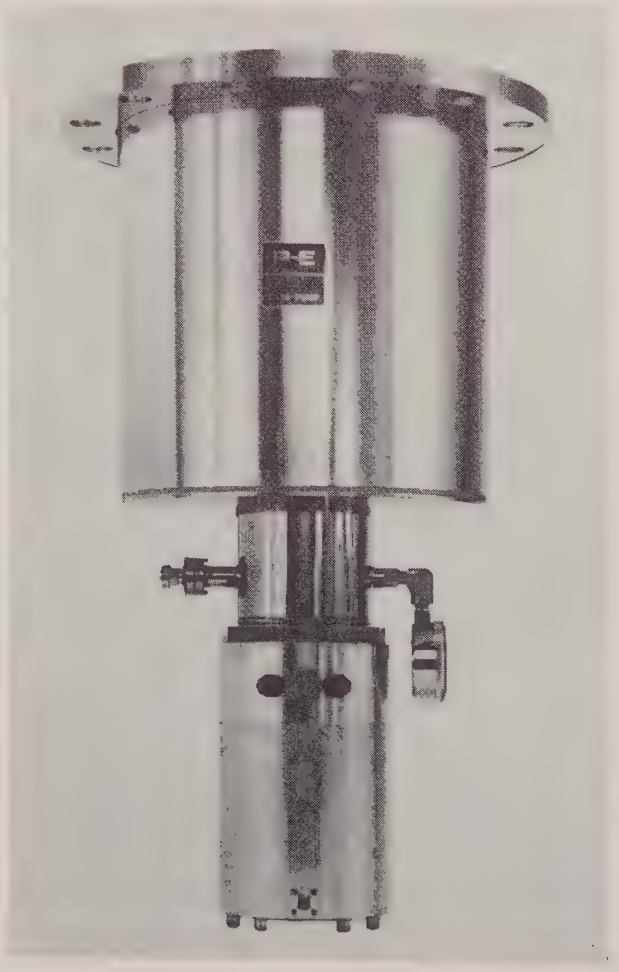


FIGURE 3.2-1 CRYOPUMP HEAT PUMP

3.2.1 Closed-Cycle Helium Cryopump System

The basic Model 4410 System is equipped with a compressor and a cryopump which utilizes a closed-cycle helium refrigerator and has a two-stage heat pump (see Figure 3.2-1). Under load conditions, it attains a temperature of 70°K on the first stage with a heat load of 7.5 W and 20°K on the second stage with a heat load of 2 W. Under high vacuum or no load conditions, these temperatures reach 45°K and 8 to 10°K, respectively. The pump must be throttled during sputtering because gas pressure greater than 1 micron ($1x10^{-3}$ Torr) for a prolonged period will thermally overload the heat pump and cause stalling. The system is equipped with a 7½-inch (6-inch ASA) ID aluminum air-operating high vacuum gate valve and an air-operated venetian blind throttling valve. The venetian blind throttle valve, as described in Section 3.2.1.1 for high vacuum pumping, is normally open and has a conductance greater than 1,100 liters/s. When the argon valve is actuated to fill the chamber to sputtering pressure, an air-cylinder is automatically actuated to drive the throttle valve to closed or throttled position. A detailed description for the cryopump and compressor is contained in Appendix B.

In addition to the throttle valve, the cryopump is supplied with a cryopump regeneration control which provides automatic control of the nitrogen vent valve, roughing and the Hi-Vac valves, and the compressor to regenerate the cryopump.

3.2.1.1 Throttle Valve

The venetian blind throttle valve is normally open with a conductance greater than 1,100 L/s. The valve automatically closes to the throttled position when the argon valve is opened to fill the chamber to sputtering pressure. This valve is preset at Perkin-Elmer, however, if it becomes necessary to reset the valve in the closed position, the following procedures should be followed:

1. Place the Automatic Pumpdown Control (APC) unit to MANUAL with vacuum system pump INTERLOCKS DEFEATED. A detailed description of the APC is provided in Section 3.2.4.

WARNING

USE EXTREME CAUTION DURING THIS MODE OF OPERATION. BEFORE SWITCHING INTO INTERLOCK DEFEATED ON THE BACK PANEL ENSURE THAT ALL SWITCHES ON THE AUTOMATIC PUMPDOWN CONTROLLER ARE IN THE CORRECT POSITION. ASCERTAIN THAT GAS, VENT, AND ROUGHING SWITCHES ARE OFF AND THE MECHANICAL PUMP, HIGH VACUUM PUMP, AND HIGH VACUUM VALVE SWITCHES ARE ON.

2. Gently close the argon micrometer valve all the way without forcing the valve. (The metering valve is not a shut-off valve.)
3. Switch GAS valve to ON.
4. Carefully adjust argon micrometer valve until chamber pressure reads 1×10^{-x} Torr on the Ion Gauge Control. (Detailed description of the WRG or DGC is provided in Section 3.3.4).
5. Switch throttle valve on the APC to closed (down) position. The WRG function switch to ST1, and the WRG Mode switch to the argon position.
6. Adjust the stop on the side of the throttle valve (located just above the pump under the baseplate) until the argon pressure reading corresponds to the desired level. For RF or DC sputtering this pressure need not exceed 20 microns.
7. Lock the throttle valve adjustment.
8. Return the APC to Auto Position and switch the INTERLOCK switch off. The throttle valve is now set and will return to this preset closure each time the gas is turned on from the front panel controls.

3.2.1.2 Cryopump Regeneration Control

The cryopump in the Model 4410 System is equipped with a controller which automatically regenerates the pump during an off-shift period. The regeneration process is controlled by the cryopump regeneration control unit mounted on the front lower right hand corner of the system panel (see Figure 3.2-2). After operating for some length of time, the cryopump must be regenerated to remove the gas molecules that have been adsorbed. The required frequency of regeneration depends on how long the cryopump is used and on the types of gas molecules that are pumped in the vacuum system. In typical production environments, it is recommended that the cryopump be regenerated at least once a week. The cryopump capacity is approximately 400,000 ton liters of argon.

FIGURE 3.2-2 CRYOPUMP REGENERATION CONTROL UNIT

Regeneration of the cryopump is initiated by pressing the CYCLE START button on the left side of the control unit's front panel.

Because the process is automatically controlled, the cryopump may be regenerated during an off-shift period. For example, after the last deposition run of the day, the regeneration cycle can be started. The cycle is then automatically completed and pump and system are fully functional at the beginning of the next shift. The regeneration cycle lasts 3½ hours and consists of the following steps:

1. The high vacuum valve is closed and the compressor is turned off.
2. A solenoid valve is opened to flood the cryopump with dry gas. Nitrogen or argon gas is recommended. The gas warms the pump and flushes adsorbed gases out of the pump through a pressure relief valve.

3. After approximately 60 minutes, the gas solenoid valve closes and an air-driven roughing valve opens, connecting the cryopump to the mechanical pump roughing manifold.
4. The cryopump is roughed for 30 minutes which reduces the pressure to 20 to 25 mTorr (microns) and assures that water vapor has been removed from the pump.
5. After roughing for 30 minutes, the roughing valve is closed and the compressor restarted. A pressure of approximately 10 microns or less is required prior to the start of cooldown. If a leak exists, the unit will be unable to reach minimum temperature and cryo start-up will not be accomplished.
6. After approximately 2 hours, the cryopump is completely chilled and control is returned to the Automatic Pumpdown Control. If chamber pressure is lower than crossover pressure, the high vacuum valve opens.

If chamber pressure has increased beyond the crossover pressure, the control will prevent the high vacuum valve from opening. With a cryopumped system, the crossover point from roughing to high vacuum may be set from 200 to 500 mTorr (microns). If the chamber pressure were to rise above 500 microns in only 3½ hours it would indicate a major leak problem or an "unclean" system.

The required frequency of regeneration depends on how often the cryopump is used and the types of gas molecules that are pumped into the vacuum system. In sputtering systems, the pump's capacity is exhausted after approximately one month of use, although a weekly recycling routine should maintain a high reserve of pumping capability. High volume of pumped gasses between regenerator cycles can require longer warm-up times either increasing regeneration time or requiring external heating application or other special procedure.

3.2.2 Turbomolecular Pumps

The Turbomolecular Pump, as shown in Figure 3.2-3, is suitable for use with Perkin-Elmer sputtering deposition equipment. A turbomolecular pump with an electronic frequency converter is available for the Model 4410 system. The oil should be changed after each 500 hours of operating time as part of the routine maintenance program (refer to Appendix C for detailed operation).

The turbomolecular pump does not require throttling and, because the pump acts as its own baffle against backstreaming, minimal baffling is required.

Manual System Start-Up (Turbo System)

After the system has been installed or if it has been completely shut-down and vented for routine or emergency maintenance, the following start-up routine should be used:

1. With the system power off, turn the key lock on the APC to MANUAL (I N T E R L O C K E D). The toggle switches as follows:
   a. High vacuum valve—closed
   b. Vent Valve—closed
   c. Roughing Valve—closed
   d. Foreline Valve—closed
   e. High Vacuum Pump—off
   f. Mechanical Pump—off
   g. LN_2 Control—off
2. Check to be sure the system is connected to the correct main power specified for your system, then turn on the main circuit breakers.

3. Turn on the mechanical pump using the toggle switch on the APC. Allow the mechanical pump to run for ½ hour to come to operating temperature and to degas the pump oil.
4. Using the manual toggle switch on the APC, close the foreline valve completely and then open the roughing valve. DO NOT OPEN THE ROUGHING VALVE BEFORE THE FORELINE VALVE IS CLOSED. In the INTERLOCKED mode, the interlocks will prevent this from happening. Use the gauge on the APC to monitor chamber roughing. When the chamber pressure reaches approximately 200 microns, close the roughing valve and open the foreline valve.
5. Read the foreline pressure using the ST2 position on the FUNCTION switch of the DGC or Wide Range Controller (WRG). (Refer to Appendix E for detailed explanation of both DGC and WRC). When the foreline pressure reaches 100 microns, turn on the high vacuum turbomolecular pump. Allow time for the high vacuum pump to attain its full pumping speed (for a turbo system this will be about 10 minutes). The turbomolecular pump frequency converter AT SPEED light will illuminate and the ACCELERATING light will turn off.
6. Open the high vacuum valve (gate valve) to the turbomolecular pump.
7. Switch the LN_2 Control on the APC to AUTO to fill the Meissner Trap.

1. Oil sump chamber
2. Current leadthrough
3. Medium frequency motor
4. Cooling coil
5. Pump body
5a. Pump body gasket
6. Wire-mesh splinter guard
7. High vacuum (intake) flange
8. Rotor
9. Stator package
10. Motor shaft with oil-feed
11. Fore-vacuum port (flange)
12. Outer annular space of oil sump chamber
13. Oil feed bores
14. Filter

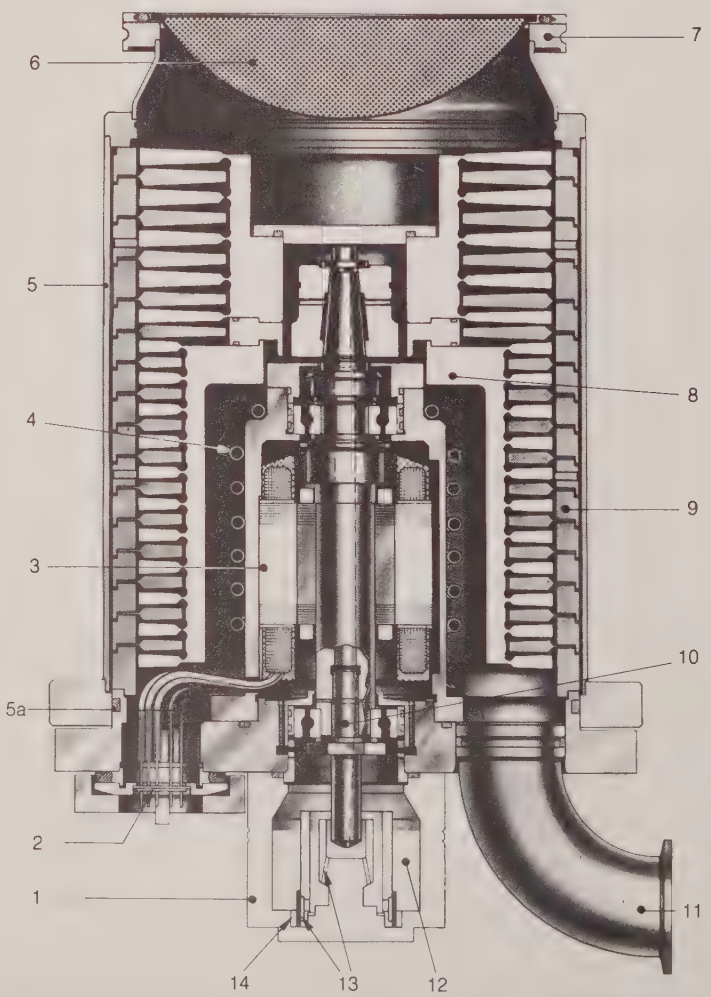


FIGURE 3.2-3 SECTIONAL DRAWING OF TURBOMOLECULAR PUMP SYSTEM

The chamber pressure will drop rapidly into the 10^{-5} Torr range. Switch the DGC or WRG FUNCTION switch to .01 EMISSION and the MODE switch to AUTO. Press the FILAMENT button and pressure will be displayed on the controller. System pressure will decline as the chamber internal surfaces degas. In a new system, pressure should be in the 10^{-7} Torr range within 2 hours. As the system is used, this time will get longer. At some point the chamber will need to be opened and the deposition shields and shutter removed and cleaned.

To vent the system, fully close the high vacuum valve and then open the vent valve. Interlocks will prevent venting with the high vacuum valve open. The pumping stack will remain under vacuum.

3.2.3 Mechanical Pump System

The roughing pump system consisting of a 36.7 CFM mechanical pump for process chamber and load lock roughing and for use in backing the high vacuum system (refer to Appendix D and see Figure 3.2-4). The roughing system in the Model 4410 is designed to pump down to 200 microns with the system mechanical roughing pump. The roughing process, in systems which are equipped with an alternative to the cryopump, such as a turbomolecular pump, is accomplished with the same mechanical pump that backs the high vacuum pump.

If the roughing system does not properly pump down, a leak may be present in the roughing line or the system and the entire system should be leak checked.

1. Terminal
2. Oil filling plug
3. Outlet port
4. Filter device – mounting flange
5. Gas ballast valve
6. Intake port
7. Oil level glass
8. Oil drain plug
9. Pump casing

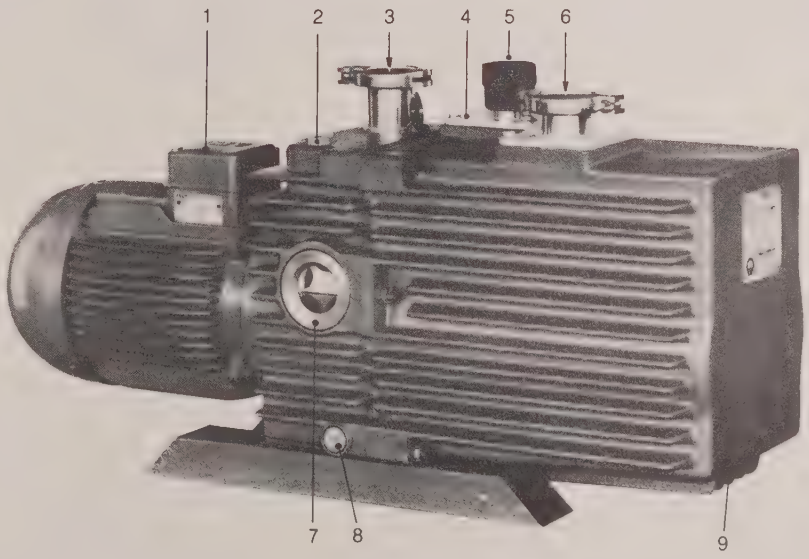


FIGURE 3.2-4 MECHANICAL ROUGHING PUMP SYSTEM

3.2.3.1 Versa Trap

Perkin-Elmer Versa-Traps were specifically designed for use in the roughing lines of the 4410 vacuum systems to prevent backstreaming of oil from the mechanical pump to the high vacuum portion of the system.

Figure 3.2-5 shows the versa trap available for use in the Model 4410 system. Table 3.2-1 describes versa trap and the associated reprocessing procedures.

FIGURE 3.2-5 VERSA TRAPS

TABLE 3.2-1

SURFACE AREA TRAP SPECIFICATION

CONSTRUCTION	304 stainless steel available with or without CFF flanges.
CAPACITY	Roll of copper mesh 22′ (559 cm) long, 5″ (127 mm) wide, which is replaceable.
MOUNTING	Can be installed in any orientation. No refrigerants or bakeout required.
OPERATING TEMPERATURE	Ambient temperature.
PRESSURE RANGE	From atmospheric pressure to high vacuum (closed system).
REPROCESSING	The metallic absorbant material may be removed and cleaned by vapor degreasing or replaced.

3.2.3.2 Water-Flow Switch

The water flow switch, as shown in Figure 3.2-6, has been designed for failsafe monitoring of water flow within the 0.1 to 10 gallon per minute range. The turbine portion of the flow switch should be installed in the outlet water line of the equipment to be protected. The passage of water through the unit will rotate the paddlewheel, thus generating a voltage which is detected by the solid-state sensing module. If the voltage indicates a water flow rate which meets the factory preset value, the relay in the electronic module will remain activated. If the water flow diminishes below the set-point, the relay will release. This relay is wired to turn off the system.

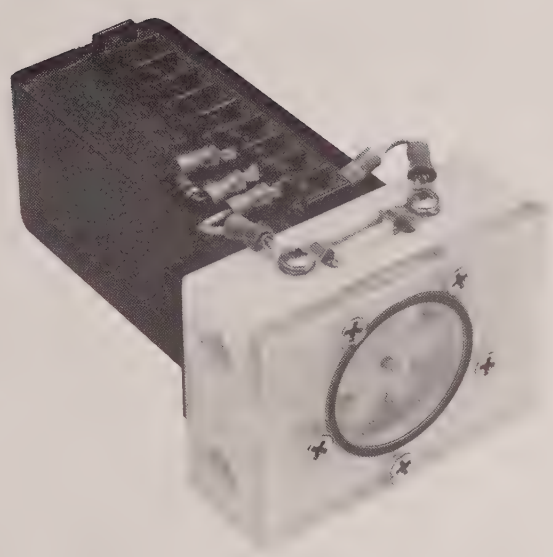


FIGURE 3.2-6 WATER-FLOW SWITCH

3.2.4 Automatic Pumpdown Control (APC)

The Automatic Pumpdown Control (APC) provides either automatic or manual pumpdown of the vacuum system. It is pushbutton operated, failsafe and totally interlocked, providing maximum possible protection to the vacuum system. The output relays are delayed in sequence so that each valve has enough time to close before another is opened. For high reliability and high noise immunity, high threshold, DTL circuitry is used. The control also includes a liquid Nitrogen Level Control with adjustable solid state timer. Pumpdown entails turning the key switch to the AUTO position and simultaneously depressing both the START and PUMP switches. Likewise, venting is accomplished by simultaneously depressing START and VENT for 2 to 5 seconds which will initiate action. The requirement that both switches be depressed simultaneously minimizes accidental venting of the system.

A display panel, as shown in Figure 3.2-7, provides a dynamic display of system operation. The indicators provide the operator with visual display of system mode and information for troubleshooting the system. The pumpdown controller has three modes of operation: (1) MANUAL (service mode); (2) INTERLOCKED MANUAL; and (3) AUTO.

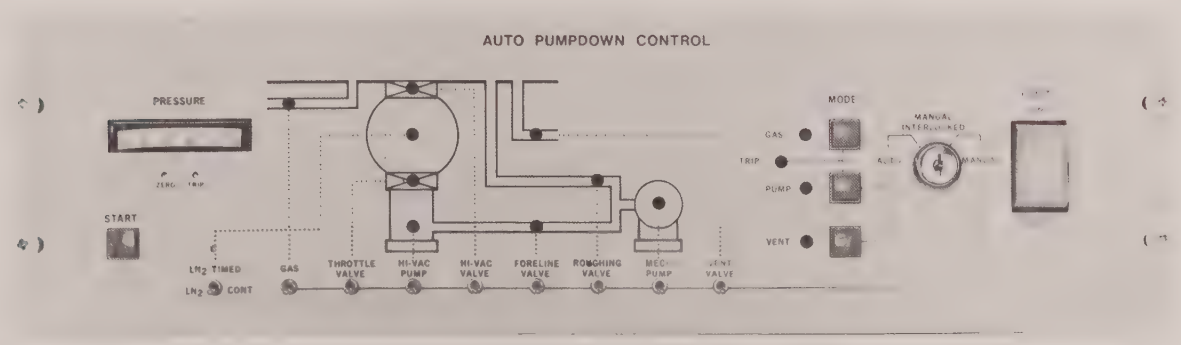


FIGURE 3.2-7 AUTO PUMPDOWN CONTROL

3.2.4.1 Manual Operation

WARNING

DO NOT USE THIS MODE DURING NORMAL OPERATION. ALWAYS KEEP THE REAR PANEL SWITCH IN "NORMAL OPERATION" POSITION. DO NOT TURN KEY TO THE MANUAL POSITION UNLESS ALL FUNCTION SWITCHES ARE IN PROPER POSITION. IMPROPER OPERATOR ACTUATION CAN CAUSE POTENTIAL DAMAGE TO WAFERS OR THE SYSTEM.

This mode is used for servicing only. Place the front panel Key Switch in MANUAL position and on the rear panel place the switch to the INTERLOCK DEFEAT position. In this mode, which is only for maintenance purposes, all valves are driven directly without interlocking.

3.2.4.2 Interlocked Manual Operation

The key switch is placed in the "MANUAL/INTERLOCKED" position for manual system operation. Although valves are driven by switches, they actuate only if the switches are thrown in the correct sequence and if proper pressure is established. The manual/interlock position, like the automatic position, is fail-safe in that no switch controlled function can be actuated out of sequence.

3.2.4.3 Automatic Operation

System operation will become fully automatic with interlock signals, pressure trip points, and time delays, when the key switch is switched to the AUTO position. The AUTO mode consists of four possible conditions:

1. VENT—During this condition, both the high vacuum and the roughing valves are closed and the vent valve is open. The GAS pushbutton can be used to interrupt venting.
2. PUMP—When this condition occurs, the foreline (if system is equipped with the turbomolecular pump), and vent valves are closed and, if the hoist is down, the roughing valve will open. The chamber is pumped down to a preset crossover pressure (TRIP), at which point the roughing valve closes, and the high vacuum valve then opens. The controller then goes into the standby condition. GAS pushbutton can be used to interrupt pumping. During this standby condition, the roughing valve is closed, and the high vacuum and foreline valves (if the system is equipped with a turbomolecular pump) are open if chamber pressure is below the TRIP point. Chamber pressure is shown on the thermocouple Gauge Meter and the crossover pressure (TRIP) can be adjusted from 10 to 500 microns with 200 microns as the recommended pressure.
3. GAS—In this condition, the high vacuum valve is open, the throttle valve (if so equipped) closed to throttled position, and the gas solenoid valve open. PUMP pushbutton shuts off the gas.
4. LOAD LOCK ROUGHING—If the system has only one mechanical pump, foreline (for the turbomolecular pumped systems) and chamber roughing valves are closed during pump down of the Load Lock. The high vacuum valve stays open. The gas is shut off during Load Lock pumping.

To activate any mode, push buttons are used simultaneously with the START button.

3.2.4.4 Interlocks and Logic Conditions

The following conditions are associated with external interlock condition:

1. High vacuum pump water flowing (turbomolecular pumps only).
2. Turbo at speed (systems with turbomolecular pumps only).
3. Hoist is down.
4. Load Lock roughing.
5. Load Lock at atmosphere (ATM).

The following depict the logic conditions:

1. Foreline valve or roughing valve can be open only if the mechanical pump is on.
2. Foreline and roughing valves cannot be open simultaneously.
3. Vent valve can be open only if roughing and high vacuum valves are closed and the Load Lock is at ATM.
4. High vacuum pump can be on only if the mechanical pump is on and cooling water is flowing (turbomolecular pumps only).
5. High vacuum valve can be open if the foreline valve is open, high vacuum pump is on (at speed if turbomolecular pump is used) and the chamber pressure is below TRIP pressure point.
6. Gas valve can be opened if the high vacuum valve is open and throttle valve is closed.
7. Roughing valve can be open if the vent and foreline valves are closed and the hoist is down.

3.2.4.5 Adjustments

The thermocouple gauge is set for ZERO with a small screwdriver through the front panel access hole labeled ZERO. This should be done only when the sensor is at a pressure of 10^{-4} Torr or lower. An access hole labeled "TRIP" sets the point of crossover from the roughing pump to the high vacuum pump. This crossover is set as 200 microns.

The liquid nitrogen timer adjusts the time between fills from 3 minutes to 2 hours. Increase the time by turning the adjustment screw above the LN_2 switch clockwise. In the continuous mode the LN_2 Controller operates exactly as described in Section 3.2.4.6. However, in the continuous mode there is no time delay between fillings. When the sensor senses that it's no longer immersed in liquid nitrogen, it starts a timer, and at the end of that time, it refills the chamber. In the continuous mode, as soon as it senses that there is no liquid nitrogen it begins to refill immediately.

NOTE: If the operator presses the STANDBY button together with the START button after the unload sequence has been activated, the unload sequence will proceed except that the Lock chamber will not be vented to atmospheric pressure. The processed substrates will be stored under vacuum.

3.2.4.6 LN_2 Controller

The LN_2 Controller consists of a level sensor, control PCB (mounted on APC), and electric solenoid LN_2 valve.

The Level sensor is a bellows pressure switch with a capillary tube that is evacuated, backfilled with gaseous nitrogen, and pinched off. This switch closes when the capillary is immersed in LN_2.

The LN_2 Control is included in the Automatic Pumpdown Control. The only adjustment on this control is the interval between LN_2 sensings. Once the LN_2 vessel is full, the sensor switch closes.

3.2.5 Digital and Wide Range Gauge Controls

The Model 4410 system may be equipped with one of two gauges that monitor the sputtering pressure and chamber high vacuum pressure. The two gauges available with the system are the Digital Gauge Control II (DGC) and the Wide Range Gauge Control (WRG) (see Figure 3.2-8). When the function switch is placed in ST1 or ST2 positions, thermistor gauges (thermal conductivity gauges) measure the pressure in the process chamber ST2 and the cryopump roughing manifold (ST1), respectively, and digitally display the readings on the instrument panel. The DGC provides accurate indication of pressure in the 2×10^{-11} Torr (or gauge x-ray limit) to 2×10^{-1} Torr range. An ionization gauge is used to cover the 2×10^{-11} Torr to 1×10^{-2} Torr range in the basic DGC. A thermistor gauge (thermal conductivity type) measure pressures in the 1×10^{-3} Torr to 2×10^{-1} Torr range (1 to 200 millitorr or microns).

The WRG provides accurate indication of pressure in the 2×10^{-11} Torr (or gauge x-ray limit) to the 1 Torr range. An ionization gauge is used to cover the 2×10^{-11} Torr to 1×10^{-1} Torr range in the basic WRG. A thermistor gauge (thermal conductivity type) is included to measure pressures in the 1×10^{-3} Torr to the 1 Torr range (1 to 1000 millitorr or microns). Detailed instructions and schematics concerning the DGC and WRG are provided in Appendix E.

The controls and indicators required for both DGC and WRG operation are located on the front panels. The functions of each control and indicator are described in Table 3.2-2.

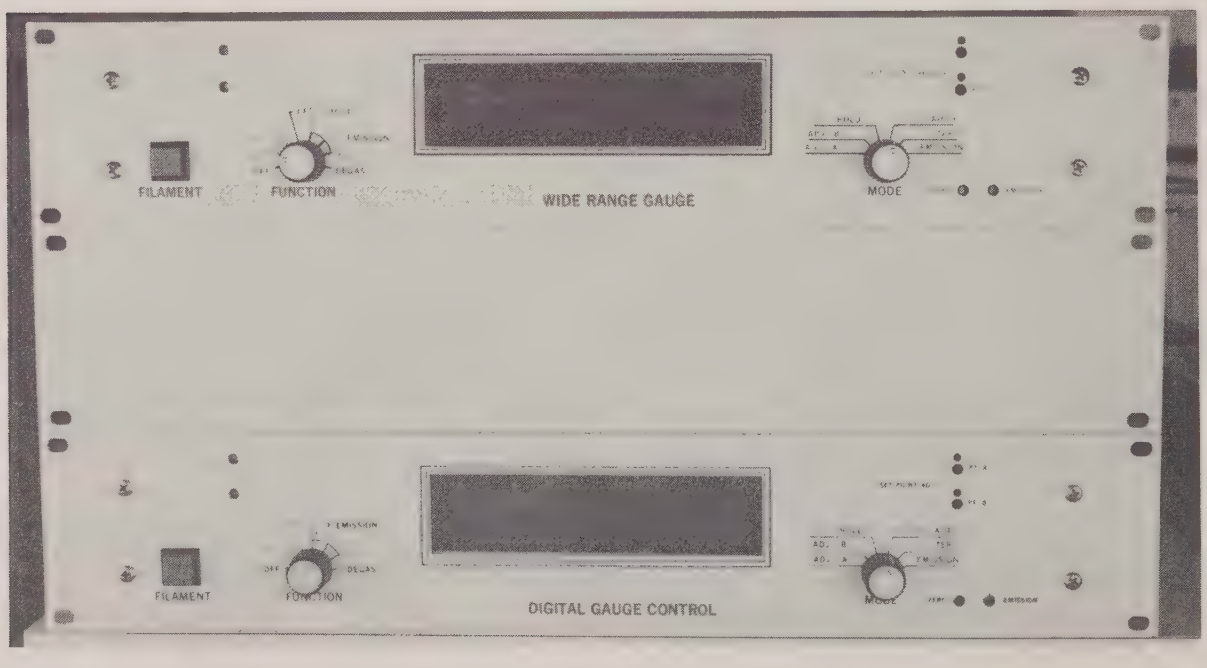


FIGURE 3.2-8 DIGITAL AND WIDE RANGE GAUGE CONTROLS

3.2.6 Operating Procedures

3.2.6.1 Ionization Gauge Tube Emission Adjustment

The following procedure should be performed before initial operation or whenever changing to a gauge tube with an emission current rating different than the tube used previously.

NOTE: The emission adjustment sets an internal reference level and the adjustment procedure should be performed before the gauge tube is connected. This will safeguard against inadvertent damage to the gauge tube.

1. Set MODE switch to EMISSION.
2. Set FUNCTION switch to any EMISSION position (except DEGAS).
3. Turn Emission screwdriver adjustment until display indicates the emission value given in the tube manufacturer's specification. For an emission of 10mA (nominal emission value for most tubulated gauges) the display should read 10.0, with the FUNCTION switch in the X1 emission mode.

TABLE 3.2-2
DGC AND WRG CONTROL AND INDICATOR FUNCTIONS

NAME	REFERENCE DESIGNATION	FUNCTION
FUNCTION Switch:	S1	
OFF		De-energizes instrument.
ST1		Connects to station 1 thermistor gauge
ST2		Connects to station 2 thermistor gauge
EXT. GAUGE*	*	Enables 10^{-2} Torr pressure range on the WRG.
EMISSION		Provides three multiplier emission indications, X.01, X.1, X1.
DEGAS		75 W of degas power for resistance heating of the grid.
FILAMENT Pushbutton Switch/Indicator	S3	Switch turns ionization gauge tube filament ON and OFF. Indicator lamp is ON when filament is on. Indicator lamp is OFF when filament is off. Switch has pushbutton action.
Five-Digit Display	VI	First display segment (VI) indicates a negative signal by showing a minus sign. This segment will also display a 1, when applicable, during hold modes, emission check, and first digit segments during thermistor gauge operation. This display also indicates second and third segments of pressure or emission in units and tenths, respectively.
	V3	Fourth and fifth display segments indicate exponent of negative powers of ten.
Display Multiplier	V2	Indicates X10 in Torr readings and is disabled when switched to functions other than pressure measuring mode.

TABLE 3.2-2 (cont'd)

NAME	REFERENCE DESIGNATION	FUNCTION
MODE Switch: ADJ-A (optional) ADJ-B	S2	 Allows display to be used to set process control set-point A. Allows display to be used to set process control set-point B.
AIR-HOLD		If FUNCTION switch is in ST1 or ST2 positions, the thermistor gauge will give an air-calibrated pressure indication. If the FUNCTION switch is in one of the emission positions, automatic range switching is disabled and the DGC or the WRG will be held in existing operating range.
ARGON-AUTO		If the FUNCTION switch is in ST1 or ST2 positions, the thermistor gauge will give an argon-calibrated pressure indication. If the FUNCTION switch is in one of the emission positions, pressure ranges will switch automatically with the exponent portion of the display indicating the existing range.
ZERO (screwdriver adjustment)		Allows the display to be used to zero the electrometer circuitry, (R2) using the zero pot on DGC or WRG front panel.
ZERO/ST1 ZERO/ST2	R4	These adjustments allow the zero pressure calibration of the two thermistor gauges. ST1 ZERO is adjustable with the FUNCTION switch in the ST1 position and ST2 ZERO is adjustable when the FUNCTION switch is in the ST2 position.
EMISSION (screwdriver adjustment)	R3	Used to set emission control level with MODE switch in the EMISSION position on the DGC and WRG
SET POINT ADJ: PT.A PT.B		 Establishes set-point A; adjacent LED illuminates when set-point A is reached. Establishes set-point B; adjacent LED illuminates when set-point B is reached.

NOTE: The Control panel for each model includes only those controls and indicators which apply to the features included in that model although holes and silkscreening are provided for field retrofit of any option.

*Only on Wide Range Gauge Controls.

When the ionization gauge is operated, the actual emission will be the value seen on the display when the MODE switch is in the EMISSION position times the multiplier given by the FUNCTION switch position. For example, if the display is set to read 10.0 and the FUNCTION switch is set at the 0.1 position, the actual emission is 10.0 x 0.1 = 1.0 mA. If an emission of 10 μA (0.01 mA) is desired, the display should be set to read 1.0 when the MODE switch is in the EMISSION position. When the FUNCTION switch is set at the 0.01 position, the actual emission in the gauge tube will be 1.0 x 0.01 = 0.01 mA or the required 10 μA. When the FUNCTION switch is in the EXT. GAUGE position, a multiplier of 0.01 is used.

3.2.6.2 Zero Adjustment of Ionization Gauge

The following procedure is used to zero the internal pressure measurement circuitry. This procedure should be performed whenever the digital display indicates a negative (−) condition or the units and tenths digits are not both zero when the MODE switch is in the ZERO position.

1. Set MODE switch to ZERO.
2. Set FUNCTION switch to the 1 EMISSION position.
3. Insert screwdriver into slotted potentiometer drive behind the hole marked ZERO (righthand end of front panel) and adjust until the display indicates 0.0 × 10^{-11} Torr. The first segment must not display a minus sign (−). If the FUNCTION switch is set at 0.1 EMISSION, the display should read 0.0 × 10^{-10} Torr and at 0.01 EMISSION, the display should read 0.0 × 10^{-9} Torr.

NOTE: Because of the automatic filament protection circuit, the unit will not allow the ionization gauge tube filament to remain on until the pressure is below 10 × 10^{-2} Torr (refer to Table 3.2-3). The thermistor gauge can be used to verify an adequately low pressure before attempting to turn on the ionization gauge filament.

TABLE 3.2-3
MAXIMUM INDICATION VS. FUNCTION SWITCH EMISSION SETTINGS

		FUNCTION SWITCH EMISSION SETTINGS							
		EXT. GAUGE		0.01		0.1		1	
		AUTO	HOLD	AUTO	HOLD	AUTO	HOLD	AUTO	HOLD
	10^{-2}	10.0	10.0	**		**	**	**	
	10^{-3}	—	18.0	10.0	10.0	**	**	**	**
	10^{-4}	—	18.0	—	18.0	10.0	10.0	**	**
DESIRED	10^{-5}	—	18.0	—	18.0	—	18.0	10.0	10.0
OPERATING	10^{-6}	—	18.0	—	18.0	—	18.0	—	18.0
RANGE	10^{-7}	—	18.0	—	18.0	—	18.0	—	18.0
(Torr)	10^{-8}	—	18.0	—	18.0	—	18.0	—	18.0
	10^{-9}	—	18.0	—	18.0	—	18.0	—	18.0
	10^{-10}	*	*	*	*	—	18.0	—	18.0
	10^{-11}	*	*	*	*	*	*	—	18.0
		FILAMENT SHUT-OFF POINTS VS. DIGITAL READOUT							

NOTES:
*Instrument will provide a more accurate indication at this pressure with higher EMISSION multiplier settings.
**Filament will not remain energized at this pressure with this power setting.

3.2.6.3 Degas Procedure

Both the DGC and the WRG models have resistance-heating (RH) type degas and switching to DEGAS with the FUNCTION switch causes a current of about 10 A to flow through the helical grid which soon becomes incandescent. For most applications, the radiation from the hot grid is sufficient to degas the rest of the tube. For ultra high vacuum, the tube should be baked with the remainder of the system.

During resistance heating degassing, pressure readings can be made while the gauge is degassing. This makes it convenient to judge the length of degassing time. Initially, the pressure indication will rise rapidly and then, after a short period, will return to a reading slightly higher than the original. As the radiation from the grid heats the rest of the tube, the pressure will slowly rise again. After several minutes, the pressure will level off, and then begin to slowly decrease. When the second decrease in pressure is observed, degassing is substantially complete. High pressure (above 1×10^{-5} Torr) can oxidize the molybdenum grid and should be avoided.

3.2.6.4 Thermistor Gauge Pressure Measurement

All front panel controls that relate to thermistor gauge operation are labeled with red lettering. Note particularly the dual function positions of the MODE switch. When the DGC or the WRG is controlling an ionization gauge, the brown letter mode is functional but when it is controlling a thermistor gauge, the red letter mode is functional.

3.2.6.5 Zero Adjustment of Thermistor

This procedure is used to balance the thermistor gauge measurement bridge when vacuum system pressure is low (5×10^{-4} Torr or lower).

1. Set the FUNCTION switch in the ST1 position.
2. Allow the instrument to stabilize by operating for at least 5 minutes and reduce pressure in the vacuum chamber to 5×10^{-4} Torr or lower.
3. Insert a screwdriver into the slotted potentiometer drive behind the hole marked ZERO ST1 in red lettering (left-hand side of the front panel) and adjust until the display indicates 00 mTorr. The minus (−) sign in the first display segment should not be illuminated; if so, calibration is invalid.
4. Set the FUNCTION switch in the ST2 position.
5. Insert the screwdriver into the slotted potentiometer drive behind the hole marked ZERO ST2 in orange lettering (adjacent to the hole used in Step 3) and adjust until the display indicates 00 mTorr. The minus (−) sign in the first display segment should not be illuminated; if so, calibration is invalid.

The thermistor gauge circuitry has now been balanced.

Table 3.2-4 shows the different switch positions necessary on both the DGC and WRG during HI-VAC (GAS-OFF) and GAS-ON Deposition or ETCH Modes.

TABLE 3.2-4

GAUGE SWITCH POSITIONS

	FILAMENT SWITCH	FUNCTION SWITCH	MODE SWITCH
DGC			
Gas off (Hi-Vac)	ON	.01	AUTO
Gas On	OFF*	ST1	ARGON
WRG			
Gas off (Hi-Vac)	ON	Ext. Gauge	AUTO
Gas On	ON	Ext. Gauge	AUTO

NOTE:

*Filament protect circuitry makes it impossible to turn on any type of ionization tube used with either the DGC or WRG, while in the thermistor (ST1 or ST2) mode of operation.

3.2.7 Power Distribution Box

A convenient feature of the 4410 Production Sputtering System is the power distribution box located inside the left rear corner of the system frame (see Figure 3.2-9). The external power source is connected to the system at a set of terminal strip contacts and the power distribution box is prewired to provide the correct power to instruments, pumps, valves, controls, power supplies, and other system instrumentation (see Figure 3.2-9, and refer to Chapter 6 for schematics).

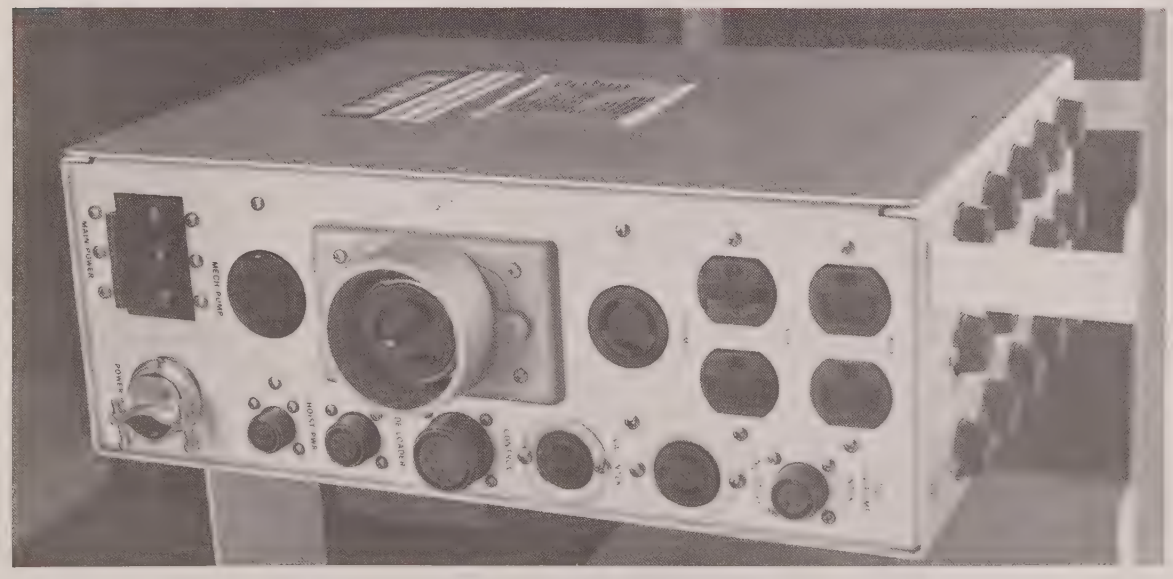


FIGURE 3.2-9 POWER DISTRIBUTION BOX

If at any time an emergency situation arises, the system can be totally shut off by switching the Main Power Circuit Breaker on the back of the distribution box to the OFF position. Also located behind the left side panel of the box are the major fuses for the various circuits controlling the system.

The following line power configurations are available with the Model 4410 System:

1. 200/208 VAC, 3/60 Hz. ("Y" or Δ)
2. 380/415 VAC, 3/50 Hz. ("Y")
3. 200/208 VAC, 3/50 Hz. ("Y" or Δ)

To connect the main power to the system, proceed as follows:

1. Remove the left end system panel by loosening the four quarter-turn screws.
2. Remove the top panel on the power distribution box mounted on the cross frame member.
3. Locate the main terminal block.
4. Refer to the appropriate schematic for the main power being connected. Refer to Chapter 6 for these schematics.
5. Pull the power cable through the opening in the rear mesh panel and through the strain relief opening in the distribution box.
6. Connect the power cable to the main terminal block.
7. Replace the distribution box and system panels.
8. Connect the power cable to the main power in the installation facility.
9. The system is now powered and ready for checkout by a Perkin-Elmer representative.

3.3 LOAD LOCK ASSEMBLY

The Load Lock assembly as shown in Figure 3.3-1, is mounted at the left of the process chamber and rests on top of the frame supporting the main pumping system.

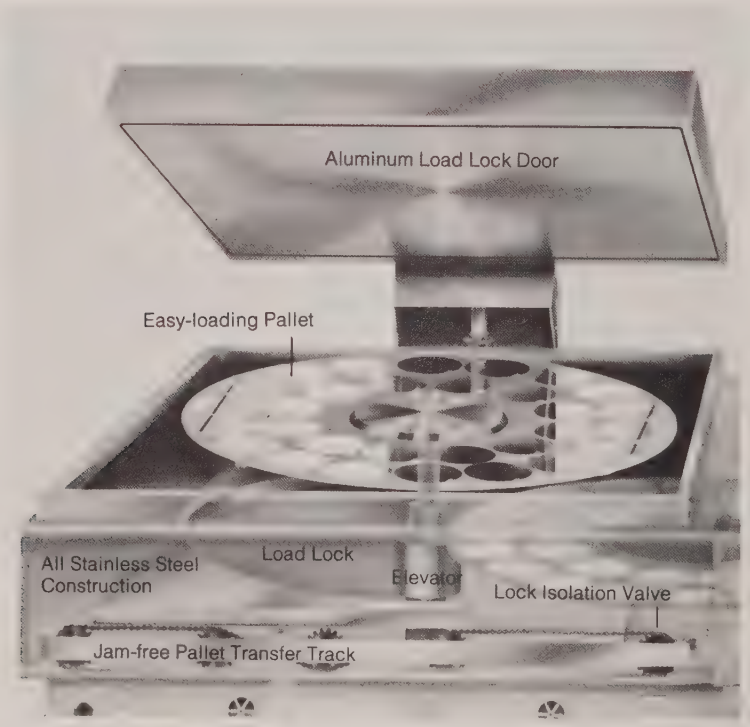


FIGURE 3.3-1 LOAD LOCK ASSEMBLY

The Model 4410 system Load Lock permits the loading and unloading of substrate wafers while the process chamber is isolated from atmosphere. It is designed specifically for fast transfer of substrate from atmosphere to high vacuum (5×10^{-7} Torr in less than 3.5 minutes). It also keeps the targets and process chamber at high vacuum, thus reducing the possibility of oxidation and atmospheric contamination. The Load Lock assures high repeatability and eliminates target cleaning operation before processing each new batch of substrates.

Load Lock pumping is provided by the mechanical pump which is shared with the process chamber vacuum system. The operation of the pump is controlled by the Load Lock control located on the left front of the Model 4410 system panel.

The Load Lock accepts a 23 ⅛-inch-diameter wafer pallet which typically holds thirty 3-inch or fourteen (or thirteen) 4-inch diameter wafers. To load a pallet of substrates, the operator places the pallet on the elevator, depresses both Load Lock door switches located on the narrow panel directly beneath the Load Lock, which closes the door and automatically initiates the pumpdown and loading sequences. Wafers may be loaded and unloaded from the pallet without removing it from the Load Lock chamber if desired.

NOTE: The switches must be kept depressed until the drive motor stops. Limit switches prevent over driving but full limit drive must occur or the load cycle will not continue. Subsequent steps in the sequence can be controlled by automatic control circuits in the Lock Control or by the operator using the control switches in the MANUAL mode. The AUTOMATIC/MANUAL mode choice is made by the operator.

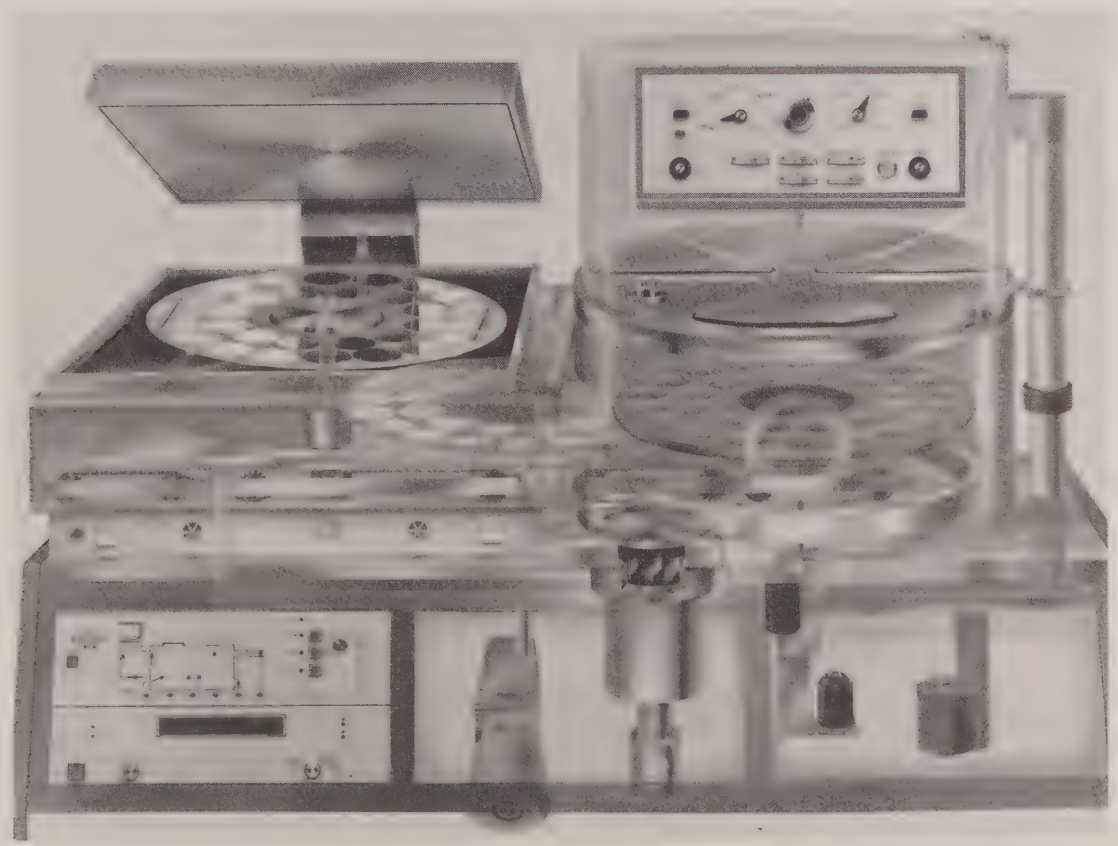


FIGURE 3.3-2 SYSTEM CONFIGURATION

The following is a brief description of Figure 3.3-2 and the automatic load sequence:

1. When the lock door is fully closed, the roughing valve opens and the Load Lock is roughed to the preset trip point pressure.

   NOTE: The trip point is set at any pressure level from 10 to 100 microns by a potentiometer located just below the meter on the lock control panel (Load Lock should be lower than pumpdown trip control). However, to minimize roughing pump oil backstreaming, 100 microns should be used.

2. The roughing valve closes, the interchamber valve door opens, and the pallet carriage transports the pallet into the processing chamber.
3. When the carriage is fully inserted, the table is raised lifting the pallet off the carriage.
4. After the table is fully elevated, the carriage retracts into the Load Lock and the interchamber valve door closes.
5. The wafer processing can now begin. The pallet is unloaded from the process chamber in a reverse manner.

3.3.1 Components

Figure 3.3-3 illustrates the principal components of the 4410 Load Lock and their relation to the processing chamber. These components include:

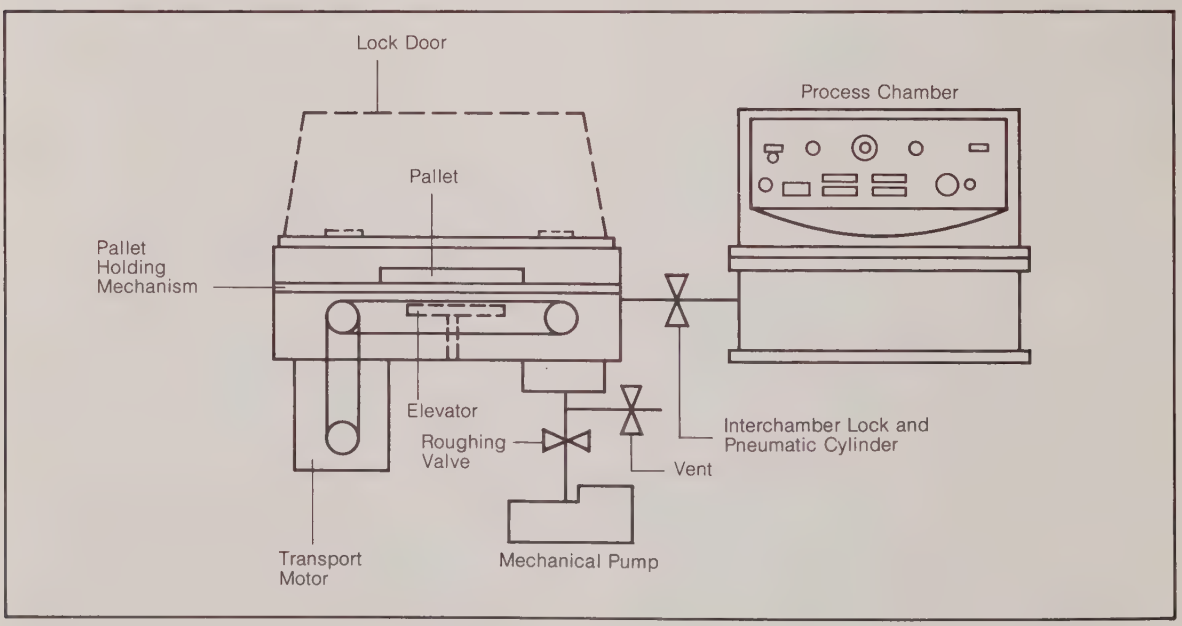


FIGURE 3.3-3 LOAD LOCK COMPONENTS

1. Lock Door—Pallets filled with substrates are loaded into and removed from the Load Lock through this door. When closed, the door seals the chamber while it is under vacuum.
2. Roughing Pump and Valve—As shown in Figure 3.3-3, this is the same 36.7 cfm (60 m^3/hr) mechanical pump, surface-area Versa-Trap, and air-operated 1.5-inch roughing valve that is shared with the process chamber vacuum system. The mechanical pump will reduce Lock

to a recommended pressure of 100 to 200 microns at the cross-over point. For systems equipped with alternatives to the cryopump, roughing is accomplished with the same mechanical roughing pump that backs the high vacuum pump.

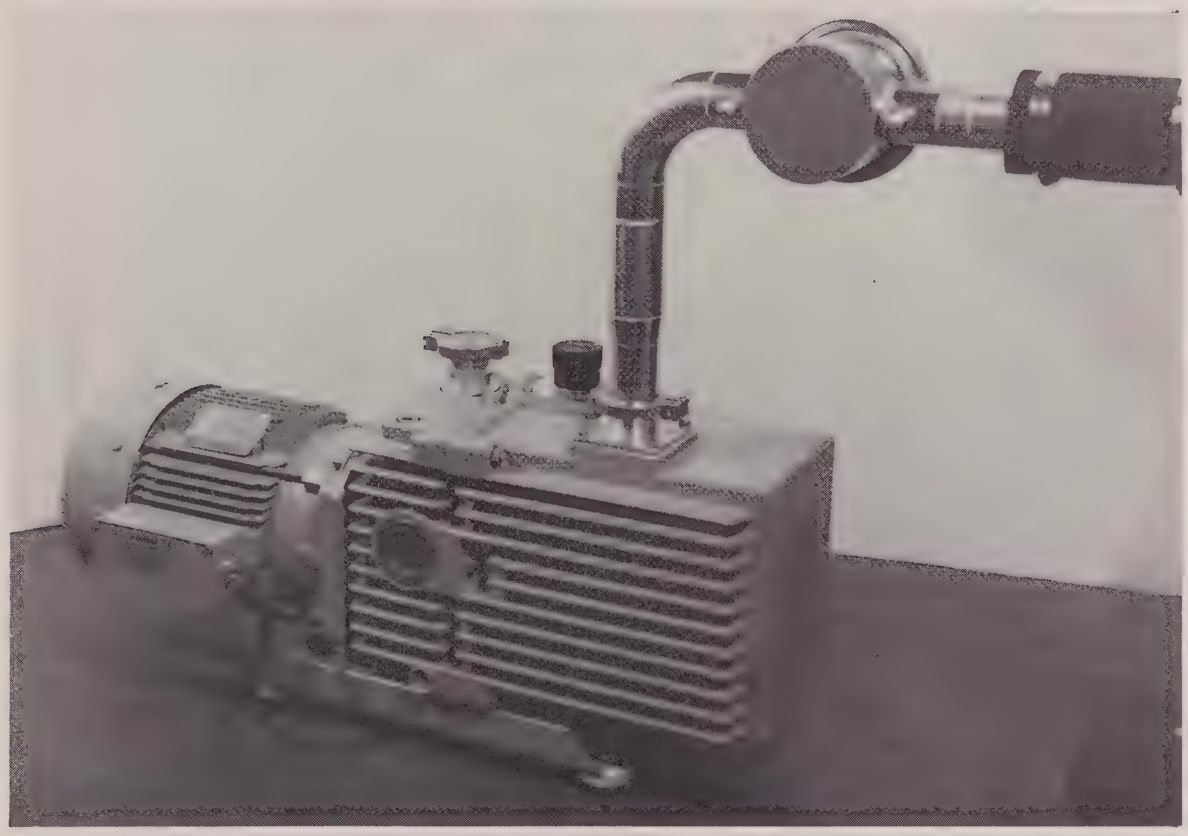


FIGURE 3.3-4 MECHANICAL ROUGHING PUMP AND VERSA-TRAP

3. Vent—The Lock chamber is vented to atmosphere through this valve before the Lock door can be opened. It is recommended that venting be done with dry nitrogen gas, at a maximum of 30 psig.
4. Elevator—This air-operated elevator automatically raises the pallet to approximately the top of the Lock chamber each time the Lock door is opened and automatically lowers into the chamber each time the operator initiates the load sequence by closing the Lock door. This feature makes pallet handling at the Load Lock more convenient; the operator never has to reach down into the Lock chamber.
5. Transport Mechanism and Drive—This device carries a pallet of substrates from the elevator to the substrate table (LOAD operation) or from the substrate table to the elevator (UNLOAD operation). A horseshoe shaped pallet carriage, riding on chain-driven friction drive wheels, is transported into or out of the process chamber while carrying the pallet (see Figure 3.3-5).
6. Interchamber Valve Door—This valve consists of an O-ring sealed door that isolates the process chamber while the Lock is pumped down to trip-point pressure. At the trip point, this valve door opens allowing the transport mechanism to move the pallet into or out of the processing chamber.

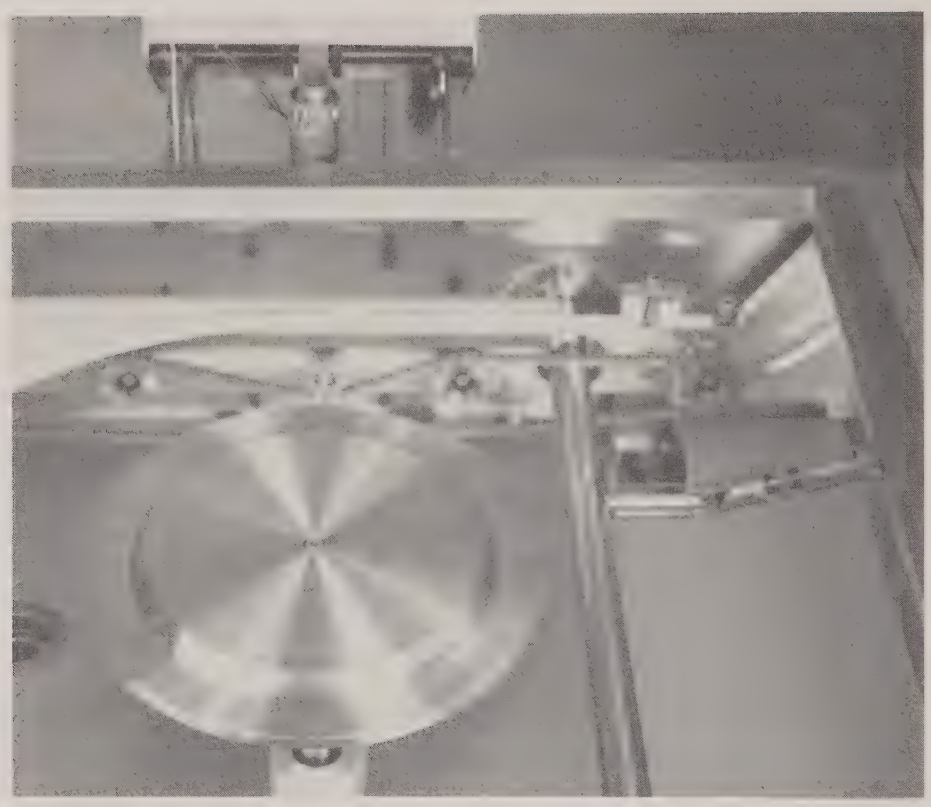


FIGURE 3.3-5 PALLET TRANSFER TRACK

3.3.2 Controls and Indicators

In addition to the mechanical elements of Figure 3.3-3, the Load Lock includes an electronic sequence controller which can be operated in either manual or automatic mode by selecting the desired mode with the key switch. Figure 3.3-6 shows the Load Lock controller. The panel features are described in detail in Table 3.3-1 and 3.3-2. The System Engineer and the operator should become thoroughly familiar with this and preceding sections of this manual before operating the Load Lock.

3.3.3 Load Lock Operation

Detailed instructions for operating the Model 4410 System Load Lock in the MANUAL and AUTO modes are presented separately below.

3.3.3.1 Manual Loading and Operating Procedure

The following procedure should be followed during MANUAL operation.

1. Put the lock controller key switch in the MANUAL INTERLOCKED position.
2. Open the Lock door using both actuating switches.
3. Set the CARRIAGE switch to OUT.
4. Set the ELEVATOR switch to UP.
5. Set the LOCK VALVE switch to CLOSED.

6. Set the PALLET switch to DOWN.
7. Place the pallet on the elevator.
8. Set the ELEVATOR switch to DOWN. This will lower the pallet onto the carriage.
9. Close the lock door using both actuating switches. Be sure the motor drive stops by itself.
10. Set the VENT VALVE switch to CLOSE.
11. Set the ROUGH VALVE switch to OPEN. This will cause the mechanical pump to rough the Load Lock.
12. Pump the Lock until the trip point is reached. This is indicated by the TRIP light on the Lock Control panel.
13. Set the ROUGH VALVE switch to CLOSE. This will terminate roughing and isolate the mechanical pump from the Load Lock. (Open foreline valve if pumped by turbomolecular pumps).
14. Set the LOCK VALVE switch to OPEN. This causes the interchamber valve door to open.
15. Set the CARRIAGE switch to IN. This causes the pallet transport mechanism to move the carriage into the processing chamber.
16. Set the PALLET switch to UP. When the CARRIAGE IN light comes on, the table will rise and pick up the pallet from the carriage.
17. Set the CARRIAGE switch to OUT. The carriage then withdraws into the Load Lock.
18. Set the LOCK VALVE switch to CLOSE. The interchamber valve door closes to isolate the Lock chamber from the processing chamber.

3.3.3.2 Manual Unloading Sequence

1. If the TRIP indicator is not illuminated, set the ROUGH VALVE switch to OPEN to reduce the Lock pressure to the trip point. (If a turbomolecular pump is used, close the foreline first).
2. Set the ROUGH VALVE switch to CLOSED (if it was opened in 1 above).
3. Set the LOCK VALVE switch to OPEN to open the inter-chamber valve door.
4. Set the CARRIAGE switch to IN (table must be in UP position).
5. When the carriage indicator labelled IN illuminates, set the PALLET switch to DOWN.
6. Set the CARRIAGE switch to OUT after the pallet is completely lowered onto the carriage.
7. When the carriage indicator labelled OUT illuminates set the LOCK VALVE switch to CLOSED.
8. Set the VENT VALVE switch to OPEN when the indicator which is labeled CLOSED illuminates.
9. When the LOCK at the ATM indicator illuminates, the Lock door may be opened by depressing both actuator switches.
10. Set the ELEVATOR switch to UP.

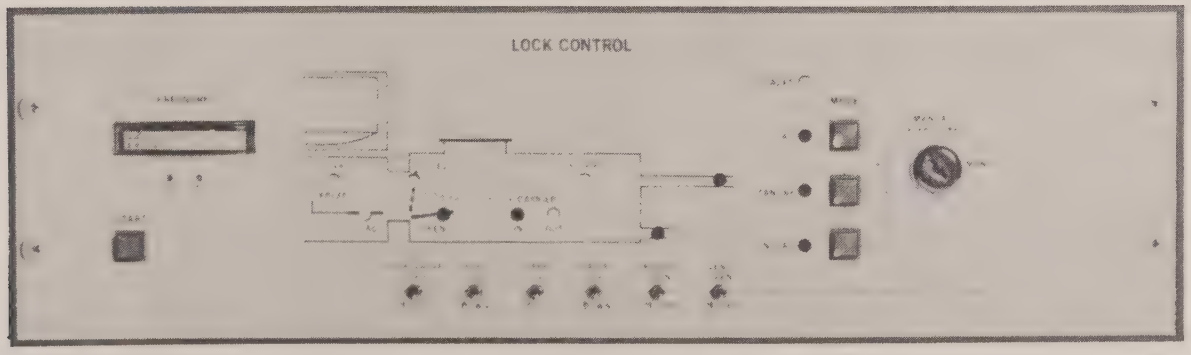


FIGURE 3.3-6 LOAD LOCK CONTROL

TABLE 3.3-1

MANUAL CONTROLS

CONTROL	FUNCTION
MODE AUTO/MANUAL INTERLOCKED/ MANUAL (three-position key switch)	Setting this switch in the AUTO position enables the push-button controls described in Table 3.3-2. Selecting the MANUAL INTERLOCKED mode enables the panel toggle switches with all interlocks functioning. Selecting MANUAL and switching the rear panel toggle switch to INTERLOCK DEFEAT permits operation of all functions independently for maintenance purposes.
WARNING DO NOT LEAVE THE REAR PANEL TOGGLE SWITCH IN THE INTERLOCK DEFEAT POSITION. INADVERTANT OPERATION IN THIS MODE CAN RESULT IN EXTENSIVE SYSTEM DOWN-TIME CAUSED BY VENTING TO ATMOSPHERE OR OTHER SUBSTRATE DAMAGING CONDITIONS AS WELL AS DAMAGE TO THE SYSTEM.	
ELEVATOR UP/DOWN (two-position toggle switch)	This switch controls the elevator pneumatic cylinder. When the switch is in the UP position, the elevator rises until it reaches the upper limit. When the switch is in the DOWN position, the elevator lowers until it reaches the lower limit.
LOCK VALVE OPEN/CLOSE (two-position toggle switch)	This switch controls the interchamber valve pneumatic cylinder. When the switch is in the OPEN position, the inter-chamber valve door opens. Conversely, in the CLOSE position the valve door closes.
CARRIAGE IN/OUT (three-position toggle switch)	This switch controls the motor that operates the transport drive mechanism. When the switch is in the IN position the drive transports the pallet carriage from the Lock into the chamber. In the OUT position the carriage is driven from the chamber into the Lock. The interchamber valve door is interlocked with the carriage IN/OUT switch. However, the friction drive prevents damage even if the interlock defeat mode is used. For service adjustments, the transport mechanism can be stopped at any intermediate point by setting this switch to the center position.
PALLET UP/DOWN	This switch controls the motor that drives the substrate table up or down. With the switch in the UP position, the table is raised to the upper limit and rotation started when "GAS ON" is enabled. With the switch in the DOWN position, the table is lowered.

TABLE 3.3-1 (cont'd)

CAUTION

CARE MUST BE EXERCISED WHEN OPERATING IN THE MANUAL MODE SO THAT TABLE AND CARRIAGE LOCATIONS ARE KEPT CLEARLY IN MIND. IF THE PALLET IS ON THE TABLE AND THE TABLE IS LOWERED, THE CARRIAGE CAN BE TRANSPORTED INTO THE CHAMBER OVER THE PALLET. RAISING THE TABLE WOULD LIFT THE CARRIAGE OFF THE TRANSPORT MECHANISM AND IT MIGHT BE NECESSARY TO VENT THE SYSTEM TO MAKE THE TRANSPORT MECHANISM OPERABLE AGAIN.

CONTROL	FUNCTION
ROUGH VALVE OPEN/CLOSED	This switch controls the Lock roughing valve. When the switch is in the OPEN position the valve opens and in the CLOSED position the valve closes.
VENT VALVE OPEN/CLOSED	This switch controls the Lock vent valve. The OPEN and CLOSED positions refer to the vent valve being open or closed.
PRESSURE ZERO/TRIP	These controls are potentiometer adjustments located just below the Lock pressure meter. The ZERO is set by first roughing the Lock, then opening the interchamber valve door to permit high vacuum pumping of the Lock. When the Lock pressure is 1×10^{-4} Torr or lower, set the meter to read zero using the potentiometer labelled ZERO. To set the pressure at which the Lock roughing ends and the interchamber valve door opens, rough the Lock chamber to the desired pressure then adjust the potentioneter labelled TRIP until the trip indicator illuminates. A pressure of 100 to 200 microns is recommended to minimize roughing pump oil backstreaming and cycle time.

TABLE 3.3-2

AUTOMATIC CONTROLS AND INDICATORS

CONTROL/INDICATOR	FUNCTION
LOAD	This switch, when depressed together with the START button, initiates an automatic load cycle. If the Lock door is lowered in the AUTO mode, the load cycle is automatically initiated and it is not necessary to depress this button.
UNLOAD	This switch, when depressed together with the START button initiates an automatic unload cycle.
STANDBY	The STANDBY switch serves two functions. If the STANDBY button is depressed (together with the START button) during Lock roughing in the LOAD cycle, the roughing will be discontinued and the load cycle will not continue beyond that point. If the STANDBY button is depressed (together with the START button) following an UNLOAD command, the unload cycle will be performed until the pallet has been withdrawn into the Lock and the interchamber valve door closed. The Lock will not be vented to atmospheric pressure. In both standby modes, the substrates are stored under vacuum. **NOTE:** To terminate the STANDBY command, use both the LOAD and START buttons or both the UNLOAD and START buttons to complete the load or unload cycle, respectively.
LOCK AT ATM (Indicator)	This indicator is located on the water flow switch/Lock door actuator panel just below the Load Lock. When illuminated, it indicates the Lock is at atmospheric pressure.
LOADED (Indicator)	This indicator is located on the Lock controller panel above the LOAD, STANDBY, and UNLOAD buttons. When illuminated, it indicates that a load cycle has been completed and there is a pallet in the chamber. **NOTE:** This indicator functions only if the automatic load sequence has been used.

3.3.3.3 Automatic Operating Procedure

The following conditions must be met before using the Load Lock in the automatic mode.

1. The transport carriage must be in the OUT position.
2. The interchamber valve door must be closed.
3. The Lock chamber must be vented to atmosphere.
4. The Lock door must be open.
5. The process chamber must be under vacuum with the high vacuum valve open.
6. The key switch on the Lock control panel must be set to AUTO.

3.3.3.4 Automatic Load Sequence

1. Place the substrate pallet on the elevator.
2. Use both door actuating switches to close the Lock door. The elevator will automatically lower the pallet onto the carriage and the LOAD indicator will illuminate on the Lock control panel. Allow the Lock door drive to run against the limit switch and stop of its own accord.
3. The LOADED indicator will illuminate when the load sequence is complete.

NOTE: If the operator presses the STANDBY button together with the START button, the Lock will continue to be roughed to the trip point pressure but will proceed no further with the load cycle. To disengage STANDBY, depress the LOAD button together with the START button and the load sequence will proceed to completion.

3.3.3.5 Automatic Unload Sequence

The unload operation typically follows a load operation and, therefore, the Lock chamber is under vacuum with the roughing valve and interchamber valve door both closed. The unload sequence consists of the following steps.

1. Press the UNLOAD button together with the START button. If the Lock pressure has risen higher than the trip point pressure, the roughing valve will open and the Lock pressure be reduced to the trip point.
2. The unload sequence is automatically executed including venting the Lock to atmospheric pressure.
3. When the LOCK at ATM indicator illuminates, the Lock door can be opened by depressing both door-actuating switches. The vent valve will automatically close and the elevator will rise to its upper limit.

NOTE: If the operator presses the STANDBY button together with the START button after the unload sequence has been activated, the unload sequence will proceed except that the Lock chamber will not be vented to atmospheric pressure. The processed substrates will be stored under vacuum.

3.4 MODEL 4410 SYSTEM PROCESS MODULE

The Model 4410 System process module includes the argon inlet, cooling water inlet and outlets, instrumentation feedthroughs, and switches. The module consists of the following major units:

1. RF impedance matching network.
2. Control panel.
3. The hoist and mechanism.
4. Process chamber top plate and cathode assembly.

3.4.1 RF Impedance Matching Network

The impedance matching network, located in the top of the unit, matches impedance of the load to the standard 50-ohm value for which the RF generator is designed. Without a proper match, the RF power generator cannot deliver maximum power to the system for the sputtering process. Instead, reflected waves travel back in the coaxial cable causing standing waves and heating of the cable and certain power generator components. Under severe circumstances, this condition could destroy the cable or power generator.

The matching network in the Model 4410 System is designed to allow independent adjustment in matching the real and imaginary parts of the impedance. A proper matching can be achieved even with wide variations in deposition parameters such as target size, target-to-substrate distance, and argon pressure. Impedance matching is controlled by LOAD and TUNE controls on the front panel (refer to Section 3.4.2).

3.4.2 Model 4410 System Control Panel

The Model 4410 System contains a complete range of controls and adjustments to vary all system control parameters that might affect the sputtering process during production. In addition, the quality of the materials and components used in its construction assure that sputtering results will be highly uniform and repeatable from batch to batch. However, since the sputtering process itself is not fully predictable, adjusting the machine to achieve a given result can be a matter of trial and error and settings will vary from machine to machine for essentially identical results. Thus a supply of sample or reject wafers should be available to try out various adjustments of the machine. After gaining familiarity with the machine, the System Engineer should have no difficulty in rapidly setting a specific system up for any process desired.

The controls and indicators are located on the front panel of the processing chamber and head assembly (see Figure 3.4-1). Table 3.4-1 describes their functions.

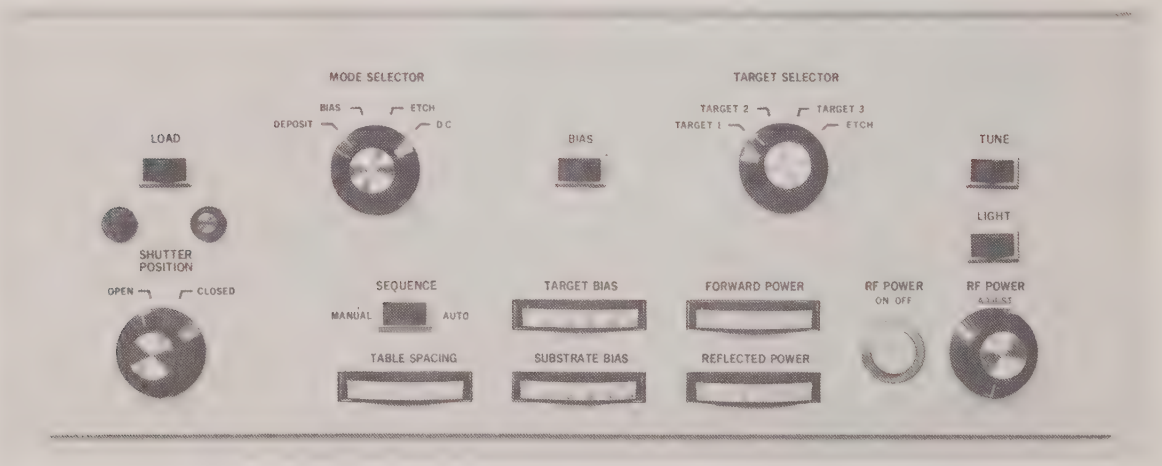


FIGURE 3.4-1 MODEL 4410 SYSTEM PROCESS CHAMBER CONTROL PANEL

In addition, an argon metering valve located on the side of the Model 4410 System control panel consists of a stainless steel needle metering valve equipped with a precision micrometer head for accurate and repeatable settings. Turning the micrometer head clockwise reduces the flow. Proper setting is empirically determined and depends upon desired argon pressure as well as system pumping capability and is effected by the venetian blind throttle valve adjustment (refer to Section 3.2.1.1). This is a precision valve that can be damaged if excess force is used when closing it.

An argon shut-off solenoid valve as shown in Figure 3.4-2, is connected in series with the argon metering valve. In operation, the argon metering valve is adjusted to give desired working pressure of argon, and the shut-off solenoid valve stops and starts argon flow without changing the metering valve setting. This solenoid valve is actuated by the GAS control on the automatic pumpdown controller.

CAUTION

NEVER TRY TO CLOSE THE METERING VALVE COMPLETELY, AS THIS WOULD DAMAGE ITS NEEDLE AND SEAT.

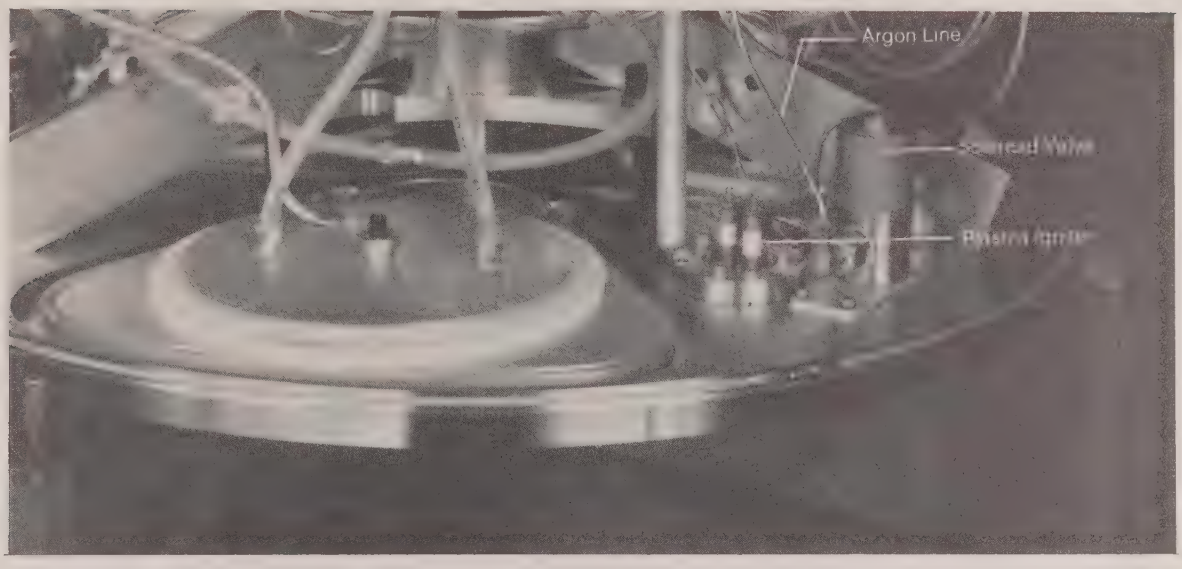


FIGURE 3.4-2 ARGON SOLENOID VALVE AND PLASMA IGNITER

TABLE 3.4-1

MODEL 4410 SPUTTERING FRONT PANEL CONTROLS AND INDICATORS

ITEM	FUNCTION
LOAD CONTROL	Adjusts inductive coupling between primary and secondary circuits of the matching network. Used in conjunction with the TUNE switch and FORWARD AND REFLECTED POWER indicators. The LOAD switch drives a motor which controls the setting for the RF tuning coil. The TUNE switch drives a motor which controls the setting of the RF tuning capacitor. These two switches are used manually to match RF power to the load. They are overridden by the Servo-Match Control when it is operated in the Automatic Tune Mode.
MODE SELECTOR	
1. Sputter Deposit	In this mode, all RF power is applied to the target; i.e. only the target is bombarded by ions and sputtered. The substrate table is grounded. Self-bias is read on the TARGET BIAS meter.
2. Bias Sputter	RF power is applied to the target, but a small amount of RF power is also applied to the substrate table. Consequently, substrates also are bombarded by ions but to a much smaller degree than the target. In many cases this technique yields higher quality deposits than RF sputtering with grounded substrates. Bias is read on the substrate BIAS meter.

TABLE 3.4-1 (cont'd)

ITEM	FUNCTION
3. Sputter Etch	All RF power is applied to the substrate table and material is removed (etched away) from the substrates by ion bombardment. Self-bias is read on the SUBSTRATE BIAS meter. Etch power should not exceed 2 kW.
4. DC Bias (Optional)	This mode is essentially the same as sputter deposit. However, instead of grounding the substrates table, a DC bias can be applied to it from an external DC power source.
BIAS ADJUST	Active only in the bias sputter operating mode. This control adjusts percentage of RF power applied to the substrate table. Varying amount of power results in varying negative self bias on the table. This bias is measured by the SUBSTRATE BIAS meter. This meter measures energy with which ions from the discharge strike the substrate table.
TARGET SELECTOR Target 1, 2, 3, & Etch	Connects output of the matching circuit to any of the three targets or substrate table. This switch has four positions. At Target 1, RF power is applied to the left target, as viewed from the front of the unit; Target 2 is the rear target; Target 3 is at the right. At the ETCH position, RF power is applied to the substrate table.
TUNE CONTROL	Adjusts parallel capacitance in the target circuit of the matching network. (Refer to LOAD CONTROL explanation).
SHUTTER POSITION Switch Open/Closed	This two-position switch actuates a motor which opens and closes rotatable disk segment shutters interposed between the substrates and target. In the OPEN position, the shutter opening permits deposition from one cathode. In the CLOSED position, it permits etching or target cleaning without cathode contamination. The shutter is adjusted so the shutter-to-table spacing permits etching, or bias deposit only through the shutter opening.
TABLE SPACING	Informs the operator of the table spacing measurement between the substrate table and the target surface. Scale is from 0 to 5 inches.
SEQUENCE SWITCH Auto/Manual	Used to switch load commands for manual or automatic remote operation. Must be in AUTO for microprocessor operation.
REFLECTED POWER Meter	Measures amount of RF power flowing back from sputtering unit to power supply due to impedance mismatching between the power supply and the load. This reflected wave combines in the cable with the forward wave to form standing waves which, in turn, cause heating of the cable. With proper adjustment of LOAD and TUNE controls, reading on the REFLECTED POWER meter will dip below 25 watts typically for RF generators of 3 kW or less. Residual reflected power is due to transitions on the cable (such as connectors, etc.) and cannot be totally eliminated.

TABLE 3.4-1 (cont'd)

ITEM	FUNCTION
RF POWER ON/OFF SWITCH	Actuates, through a special logic circuit, a high-voltage relay in the RF power generator. The on/off function is interlocked by a pressure interlock switch so RF voltage cannot be applied to targets while they are exposed to atmospheric pressure. Applying high RF voltage to targets at atmospheric pressure can result in arcing and breakdown around target edges. The target assembly is designed for operation at low pressures where the arc breakdown distance is much longer than at atmospheric pressure.
RF POWER ADJUST CONTROL	Governs power output from the RF power generator. Power is measured by a directional coupler in the generator and measured value is displayed on the FORWARD POWER meter.
LIGHT SWITCH	Manual Control of filament igniter to allow visual observation in the chamber. When depressed, the chamber will be illuminated by the incandescent filament.

3.4.3 Hoist Mechanism

The Model 4410 System is equipped with a heavy-duty electromechanical hoist to permit easy opening of the processing chamber. The hoist was designed to fulfill the requirements for a hoist which would be capable of lifting large and heavy loads (such as top plate/matching network units comprising the system head assembly) or up to 600 pounds (½ hp motor). The rugged design incorporates heavy tubing and a bronze lift nut for relatively chatter-free operation (see Figure 3.4-3 and 3.4-4).

A hoist interlock or safety switch prevents operation of the hoist when the process chamber is under vacuum. This interlock prevents accidental activation of the hoist when the hoist switch is energized. The hoist can be raised when the chamber is vented to atmospheric pressure.

At the back of the unit near the hoist adapter, a 50-ohm RF power cable from the generator is connected to the RF connector (N-type). On both sides of the hoist adapter, located on the wrap-around cover panels, are four screw leads for adjustable three turn panel locking pawls.

WARNING

NEVER OPERATE THE UNIT WITHOUT COVER PANELS SECURELY IN PLACE. HIGH RF VOLTAGE DEVELOPS IN THE CIRCUITRY DURING OPERATION. DO NOT DEFEAT THE INTERLOCKS.

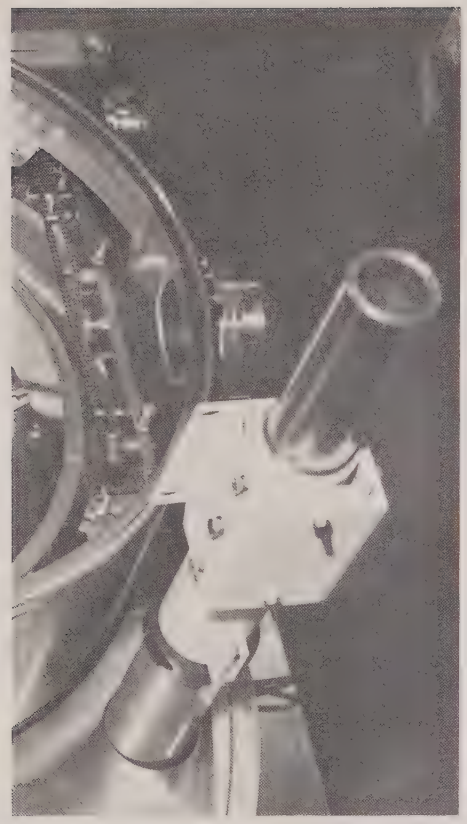


FIGURE 3.4-3 HOIST COLUMN

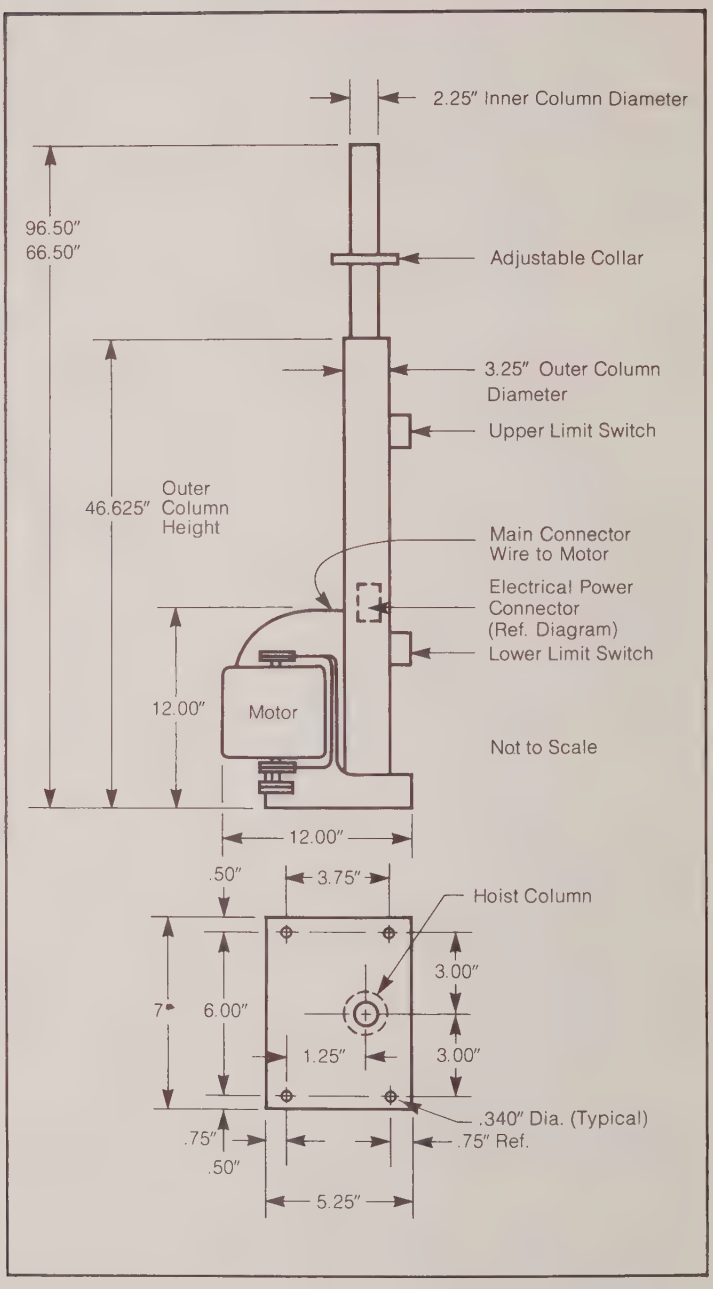


FIGURE 3.4-4 HOIST ASSEMBLY

As shown in Figure 3.4-5, located on the back panel of the unit are the following connections.

1. Servo-Match Control (J2)
2. Table Assembly (J6)
3. RF Generator (P1)
4. DC Magnetron Interlocks (P8)
5. AC Power (P10)
6. Microprocessor (J20)
7. Microprocessor (J4)
8. RF connection
9. RF H_2O IN/OUT
10. DC H_2O IN/OUT
11. Gas IN
12. Differential Vacuum

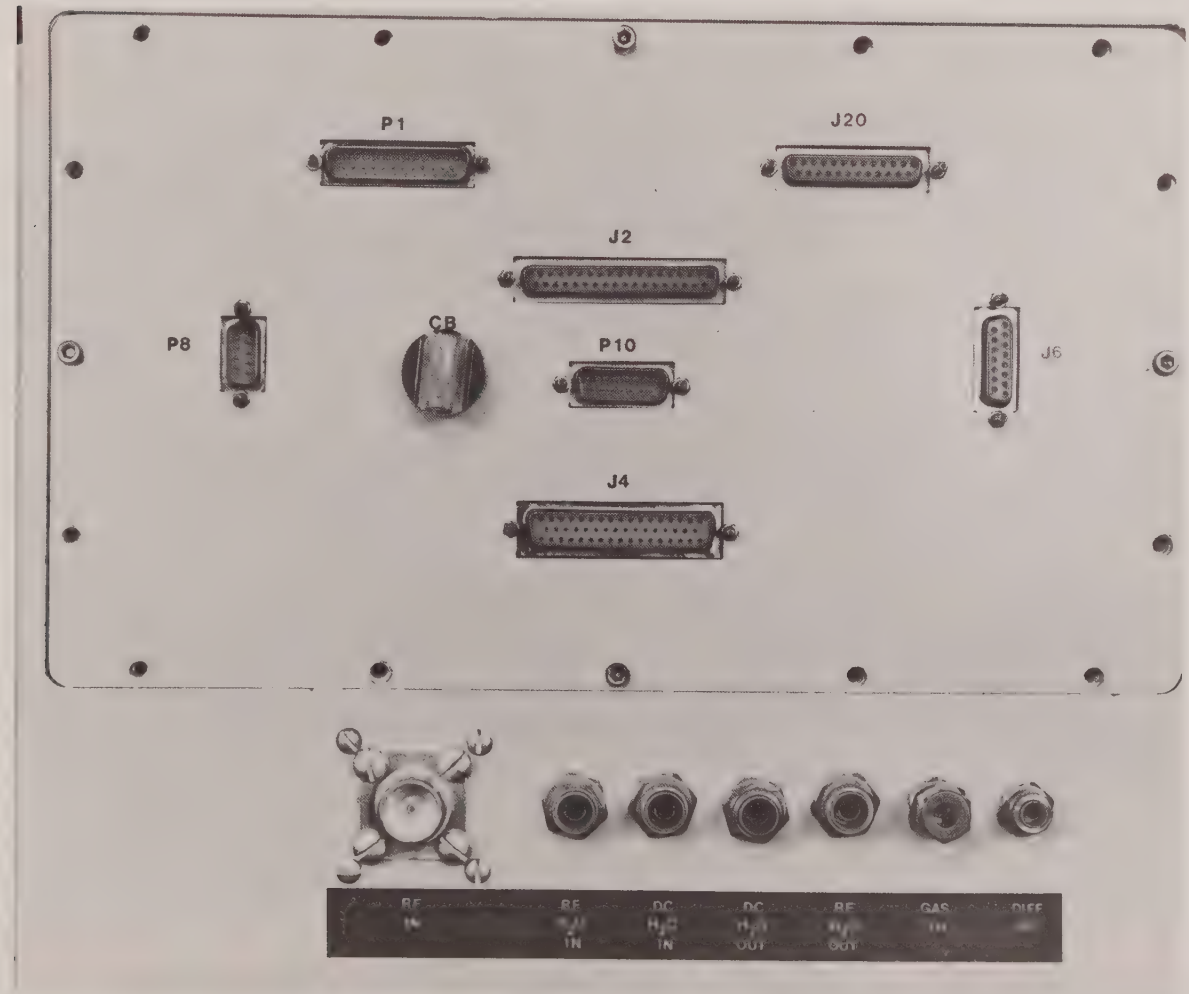


FIGURE 3.4-5 BACK PANEL CONNECTIONS

3.4.4 Process Chamber and Process Module Assembly

The Model 4410 System process chamber is provided in a water-cooled design configuration. Comprising the process chamber is the top plate with head assembly, cathode and shutter and support assemblies, gas inlet, automatic plasma igniter, viewports for observing the sputtering process, the annular table and the table rotation drive mechanism, and the Meissner Trap.

The Model 4410 System standard chamber is an ambiently-cooled conventional cylindrical vacuum chamber as standard equipment. As long as the chamber is kept clean and properly maintained and leak free, down time will be minimized and uniformity of production quality assured.

The water-cooled chamber option is used to further cool the chamber to prevent degasing or to prevent overheating when either Load Lock or the cathode heaters are utilized during certain sputtering processes. The water-cooled chamber is surrounded on the outside wall by an additional stainless steel jacket to allow for circulation of water. The design of a specific Model 4410 System chamber is dictated by the needs of the user.

3.4.4.1 Delta or Circular 8-inch RF Cathode Assemblies

Up to three circular or delta-shaped cathode assemblies can be installed on the Model 4410 System. The circular 8-inch-diameter cathodes may be any combination of conventional RF or DC magnetron configuration, where the delta shaped cathodes are DC Magnetron only. The circular RF or DC cathodes are mounted on the top plate in a special delta to 8-inch round adapter (see Figure 3.4-6).

The circular cathode assemblies are provided with an aluminum oxide (ceramic) insulator, top plate, and target cathode plate fabricated of Oxygen Free High Conductivity (OFHC) copper for efficient cooling. All cathode assemblies can be easily changed within minutes.

Target materials can be attached to the cathode backing plate using various techniques such as brazing, soldering, epoxy bonding, bolt-on, or Magnabond® methods.

The following are step by step instructions of installing the circular RF 8-inch cathode/target into the target insulator:

CAUTION

TO PREVENT CONTAMINATION OF THE SPUTTERING TARGET, INSULATOR OR BACKING PLATE, DO NOT HANDLE WITH BARE HANDS. USE CLEAN RUBBER OR PLASTIC GLOVES AND CHEMICALLY CLEAN COMPONENTS.

1. Place the cathode/target face down on a clean sheet of lint-free paper and screw the specially provided set screw into the center hole of the backing plate (see Figure 3.4-7).
2. Inspect the side facing up for cleanliness. Remove any particles of dust from the sealing surface.
3. Install a lightly greased O-ring (standard size No. 258 for the 8" cathode) in the groove in the insulator center hole.
4. Hold the insulator with the machined detail facing down (see Figure 3.4-8) and install insulator on the target holder. Push the insulator down until it sets against the back side of the cathode/target (see Figure 3.4-8).

WARNING

MAKE SURE NOT TO CUT OR ROLL THE O-RING (see Figure 3.4-9).

5. Install a No. 210 O-ring (see Figure 3.4-10) in the inner groove and a No. 252 O-ring in the outer groove of the cover plate. The cover plate is also known as the brass top cap.
6. Install the cover plate onto the holder/insulator assembly, making sure O-rings are not damaged. Secure assembly with a thumb nut on the #3/8-16 thread. This thumb nut also serves as an adjustment for target position to compensate for various thickness of target materials (see Figures 3.4-11 and 3.4-12).
7. Install snap ring in groove on #3/8-16 screw. This prevents backing the target out far enough to break the water seal.
8. Install a No. 268 O-ring in the insulator groove.
9. Install target assembly in the delta to round adapter target hole already installed in the system top plate, keeping the #10 screw hole in the cover plate near the RF strap leading from the matching network.
10. Connect cooling water lines to the target.
11. Connect RF strap or DC lead to the target using a #10 thumbscrew.

FIGURE 3.4-6 DELTA TO 8-INCH ROUND ADAPTER

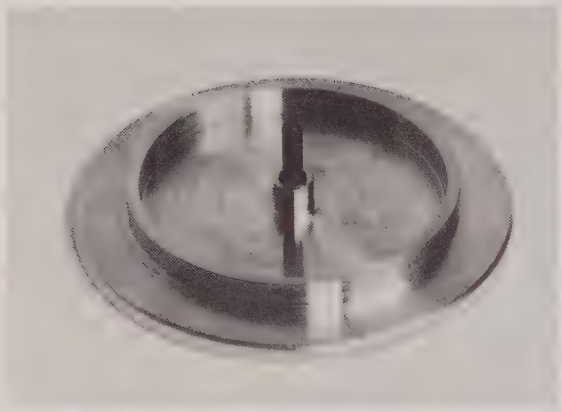


FIGURE 3.4-7 CIRCULAR RF CATHODE/TARGET ASSEMBLY

FIGURE 3.4-8 INSTALLING INSULATOR ON CIRCULAR RF CATHODE/TARGET ASSEMBLY

FIGURE 3.4-9 CORRECT INSTALLATION OF CIRCULAR RF INSULATOR

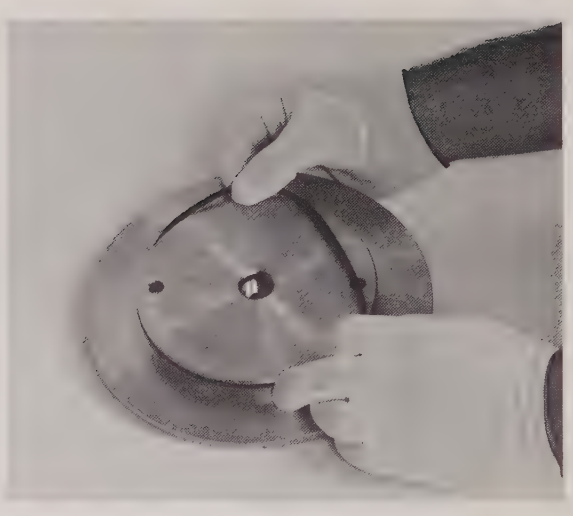


FIGURE 3.4-10 INSTALLING O-RING IN CIRCULAR RF COVER PLATE

FIGURE 3.4-11 INSTALLING COVER PLATE ON CIRCULAR RF HOLDER/INSULATOR ASSY.

FIGURE 3.4-12 LOCKING THE COVER PLATE ON THE CIRCULAR RF TARGET ASSEMBLY

3.4.4.2 Circular 8-inch RF Magnetron Assembly

The 8-inch-round RF magnetron assembly is used to take advantage of the properties of magnetically confined plasma or magnetron sputtering. The RF magnetron is identical to the round cathode as described in Section 3.4.4.1. It consists of a conventional 8-inch-diameter RF cathode with a copper target backing plate, a ceramic insulator, and top plate (see Figures 3.4-7 through 3.4-12). A special magnet assembly behind the cathode as shown in Figure 3.4-13, is installed in the delta to round adapter before the water and RF connections are made.

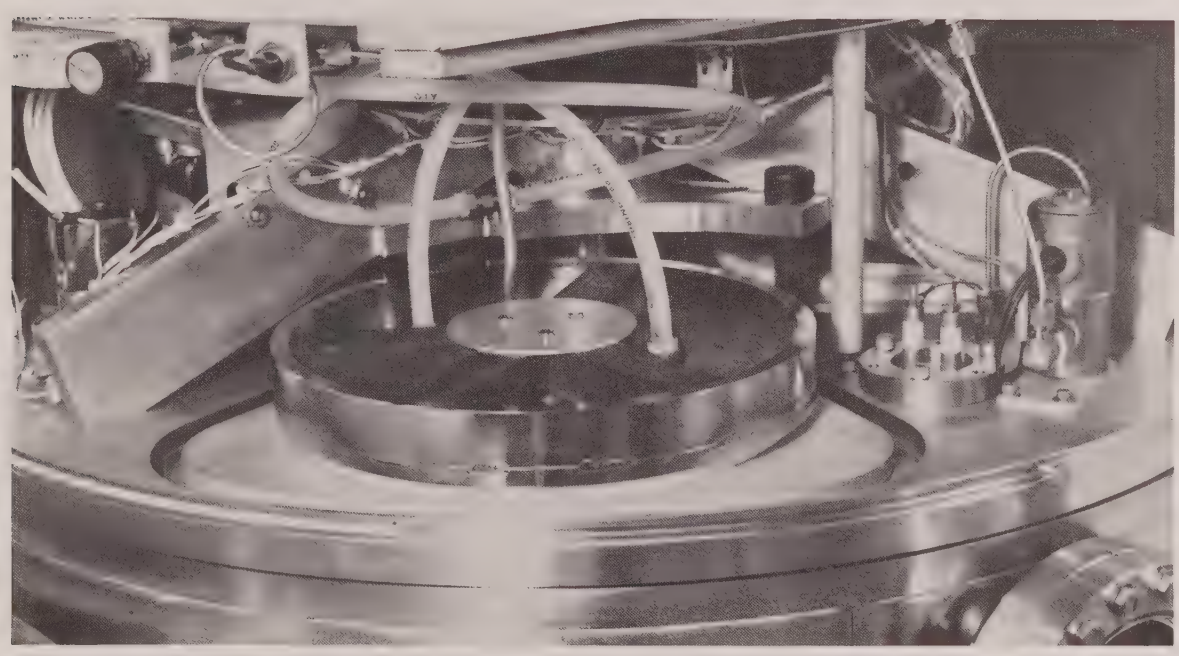


FIGURE 3.4-13 CIRCULAR RF MAGNETRON INSTALLATION

The RF Magnetron is used where addition of the magnetic field deflects the secondary electrons produced in the sputtering process away from the substrates. Use of this option permits deposition of materials requiring RF sputtering, (such as quartz or other dielectrics) on substrates that must be kept at a lower temperature than can be obtained conveniently with normal diode sputtering. A relatively low magnetic field is superimposed on the plasma, sufficient to deflect secondary electrons but not strong enough to substantially change plasma impedance characteristics.

In this way, low substrate temperature operation is possible without requiring a radical change in the matching network. With this option, the operator may switch from a normal non-magnetron RF target to an RF magnetron target and still obtain excellent RF tuning.

WARNING

THE MAGNET ASSEMBLY SITS ON THE HIGH VOLTAGE SIDE OF THE TARGET INSULATOR, AND THE ENTIRE MAGNET ASSEMBLY IS AT POTENTIALLY LETHAL HIGH VOLTAGE DURING OPERATION. THE SIDE PANELS MUST BE IN PLACE DURING OPERATION. DO NOT DISABLE THE INTERLOCK SWITCHES. THEY ARE THERE FOR YOUR SAFETY.

The RF magnetron operation is almost identical to normal RF diode sputtering. When viewed through the chamber viewing window, plasma will appear brighter in a ring near the periphery of the target. This is normal operation. Although the magnetic field is not strong enough to cause the dramatically enhanced sputtering rate characteristic of DC magnetrons, there is up to 10% higher rate with a change to the sputtering distribution pattern corresponding to the magnetic fields. For ±7% uniformity, it is necessary to operate with a deposition shaper and with the annular table in continuous rotation.

3.4.4.3 Circular 8-inch DC Magnetron Assembly

The DC Magnetron is designed to take advantage of the sputter rate enhancement to be obtained by increasing the magnetic field in front of the target surface to a level at which substantial plasma enhancement results. (Figures 3.4-14 through 3.4-19 show the DC magnetron cathode assembly).

CAUTION

TO PREVENT CONTAMINATION OF THE SPUTTERING TARGET INSULATOR OR BACKING PLATE, DO NOT HANDLE WITH BARE HANDS. USE CLEAN RUBBER OR PLASTIC GLOVES AND CHEMICALLY CLEAN COMPONENTS.

1. Place the backing plate assembly with bonded target face up on a clean sheet of lint-free paper.
2. Inspect the side facing up for cleanliness. Remove any particles of dust, etc. from the sealing surfaces.
3. Install a lightly greased O-ring in the insulators inside O-ring groove.
4. Set the insulator adjustment support ring down over the target and onto the backing plate. This is designed to be a very loose fit (see Figure 3.4-14).
5. Hold the insulator with the machined detail facing up and install over the target pressing it down on the backing plate until it sets against the adjustment support ring (see Figure 3.4-15).

WARNING

DO NOT TOUCH THE SURFACE OF THE TARGET MATERIAL. ALSO, MAKE SURE NOT TO CUT OR ROLL THE O-RING OVER THE TARGET MATERIAL.

6. Install an O-ring (Viton 2-228, P/N 122-140-200) in the inner groove and an O-ring (Viton 2-259, P/N 120-018-000) in the outer groove of the brass cover plate (see Figure 3.4-16).
7. Turn the backing plate assembly with insulator installed over, with the target now face down.
8. Install the cover plate onto the backing plate assembly, making sure the six screw holes line up with the holes in the cover plate (see Figure 3.4-17).
9. Install the six 1/4-20 socket-head screws (½ inch long, P/N 172-176-000) and carefully and evenly tighten to ensure the cover plate sets without pinching an O-ring.
10. Hold the magnetic assembly with the center protruding pole piece down. Gently set the magnetic assembly down over the cathode assembly, making sure the water lines fit through the magnets (see Figure 3.4-18).

CAUTION

DO NOT HOLD THE MAGNETIC ASSEMBLY WITH YOUR FINGERS BETWEEN IT AND THE CATHODE ASSEMBLY; WHEN INSTALLING, AN INJURY CAN OCCUR WHEN THE MAGNETIC FIELD ATTRACTS THE CATHODE.

11. Install the three 1/4-20 socket head screws (1.5 inch long, P/N 176-013-000) in the backing plate. Tighten only to the point at which they touch the adjustment support ring. These screws serve as an adjustment for target position, to compensate for various thicknesses of target materials (see Figure 3.4-19).
12. Before installing the cathode assembly in the delta to round adapter system, turn the completed assembly back over and install an O-ring (Viton 2-269, P/N 121-397-000) in the outside insulator O-ring groove.

The DC magnetron target assembly is installed in the system in the same manner as the RF target assembly except for the adjustment of the target with respect to the top plate. The vertical adjustment is made by means of three jacking screws on the periphery of the backing plate assembly.

The screws should be used to position the target face in the same plane as the interior surface of the system top plate. The short water leads and high voltage stud should be installed in the assembly before mounting the magnet assembly. In this way, the main water leads and power supply cable can be installed without undue effort.

WARNING

THE MAGNET ASSEMBLY SITS ON THE HIGH VOLTAGE SIDE OF THE TARGET INSULATOR, AND THE ENTIRE MAGNET ASSEMBLY IS AT LETHALLY HIGH VOLTAGE DURING OPERATION. THE SIDE PANELS MUST BE IN PLACE DURING OPERATION. DO NOT DISABLE THE INTERLOCK SWITCHES. THEY ARE THERE FOR YOUR SAFETY.

Pole pieces of the magnet assembly are brought very close to the target surface. In this way, the magnetic field in front of the target face is maximized and made substantially parallel to the target surface. Although the DC Magnetron can only be used with conducting materials, the following advantages are achieved for metallization processes:

1. Substantially higher deposition rate than normal diode sputtering.
2. Deflection of secondary electrons so substrates remain cooler.

Cool operation with the DC magnetron is more pronounced than with the RF magnetron because the magnetic field strength is greater for more effective electron deflection. The DC magnetron operates at about one half to one fourth the voltage, depending on power level of the RF magnetron, and the lower energy secondary electrons are easier to deflect.

NOTE: In spite of the extraordinary operating characteristics of the DC magnetron, the process is still restricted by the limitations peculiar to DC sputtering. For stable, arc-free sputtering of oxidizable targets such as aluminum, titanium, etc., the system residual gas pressure must be maintained below 5×10^{-7} Torr. If arcing or unstable plasma is experienced, shut off the DC power supply and argon and immediately read the residual gas pressure in the chamber using the ionization gauge. If pressure exceeds 1×10^{-6} Torr, the system is not adequately clean. If good maintenance and handling procedures are used, satisfactory operation will result.

FIGURE 3.4-14 INSTALLING INSULATOR ADJUSTMENT SUPPORT RING

FIGURE 3.4-15 INSTALLING INSULATOR ON CATHODE/TARGET ASSEMBLY

FIGURE 3.4-16 INSTALLING O-RING IN COVER PLATE

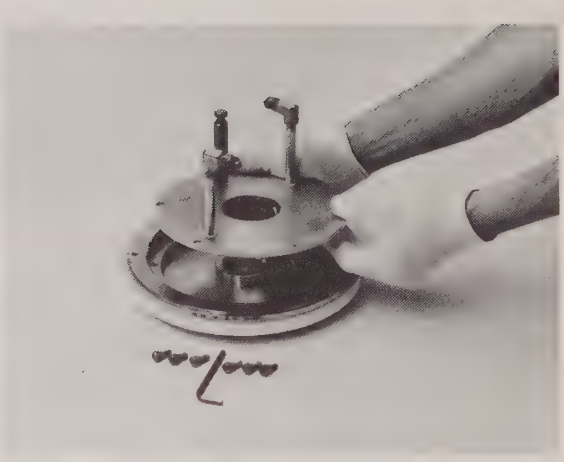


FIGURE 3.4-17 INSTALLING COVER PLATE ON CATHODE/TARGET ASSEMBLY

FIGURE 3.4-18 INSTALLING MAGNETIC ASSEMBLY ON CATHODE/TARGET ASSEMBLY

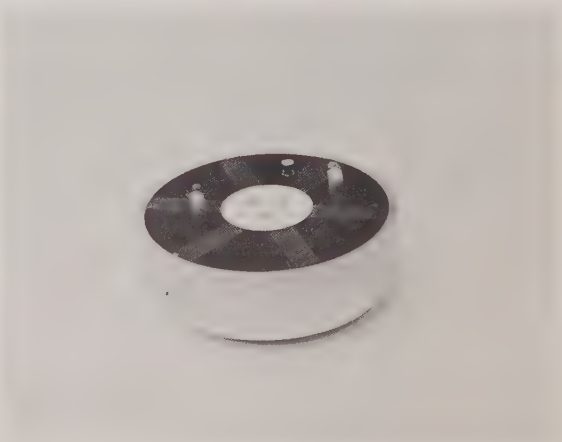


FIGURE 3.4-19 COMPLETED DC MAGNETRON CATHODE/TARGET ASSEMBLY

Operation

The operation of the DC magnetron is simple and straightforward if the procedures given here are followed. The DC magnetron can best be operated anywhere in the pressure range of 3 to 10 microns. At higher pressure, increased scattering of the deposited material takes place and at lower pressure, plasma ignition is difficult to obtain. The operation procedure follows:

1. Load the substrates and pump the system to a base pressure in the 10^{-7} Torr range. With reactive materials, the base pressure should be below 5×10^{-7} Torr. This prevents an excessive buid-up of residual gases as interior parts warm up during the sputtering process.
2. Check that the DC Magnetron cathode has water flow of at least 1.5 gpm (5 liters/min). Interlocks will prevent the DC supply from being turned on without adequate water flow.

NOTE: The power density on the DC Magnetron target can be as high as 20 W/cm² compared to 5 or 6 W/cm² for an RF target. If catastrophic failure is to be avoided from target debonding, proper cooling (1.5 gpm minimum of water) must be maintained.

3. Turn on the argon supply and establish the desired sputtering pressure. This should be in the 3 to 10 microns (milliTorrs) range.
4. Check to be sure the shutter is closed in front of the Magnetron cathode.
5. Turn on the DC power supply in the CONTINUOUS mode and bring the power to about 1 or 2 kW. At this point the plasma should be ignited. If it does not ignite, the DC voltage will be about 800 V with no current. To ignite the plasma, use either the hot filament igniter with controls on the sputter head (RF generator must be on) or the pressure can be raised momentarily to about 15 microns, then reduced after ignition. To use the hot filament igniter, turn on the RF generator, turn RF POWER ADJUST to zero, then press the RF POWER ON button. There will be no RF power but the igniter will come on. This will assist the DC ignition. Normally, this will be necessary only if an oxide layer exists on the surface of a target used for the first time.

NOTE: During this initial operating period, lasting up to 10 minutes for a contaminated target, the plasma will be unstable and arcing can occur on the target surface. This is normal and should not cause concern. If the unstable arcing condition lasts longer than 10 or 15 minutes, inspect the target for excessive contamination. Clean if necessary.

6. When the plasma stabilizes, as evidenced by a quiescent condition on the DC power supply meters, adjust power to the desired operating level.
7. Make sure the substrate table is in continuous motion, put the DC power supply in the TIMED mode (with the timer set for the desired deposition time), and open the shutter.
8. The DC power supply will shut off automatically at the end of the time interval.

The substrates may now be unloaded.

Table 3.4-2 compares the operating characteristics of RF and DC magnetrons to conventional RF diodes.

TABLE 3.4-2

CATHODE OPERATING CHARACTERISTICS

Operating Characteristics	Conventional RF Diode*	RF Magnetron*	DC Magnetron**
Substrate Temperature at High Power Operation	Over 400°C	Less Than 400°C	Less Than 400°C
Dielectric Material Deposition?	Yes	Yes	No
Rates For Metals	Conventional RF Rates	Slightly enhanced RF Rates	High Rate Operation
Rates for Dielectrics	Conventional RF Rates	Slightly enhanced RF Rates	Non-operational

NOTES:
*Circular Cathodes
**Circular and Delta shaped cathodes

3.4.4.4 Delta Cathode DC Magnetron Assembly

The Delta-shaped cathodes are specifically designed to reduce deposition time and increase the throughput in production sputtering systems with rotating annular substrate tables (see Figure 3.4-20). The targets are shaped similar to a sector of a circle, a configuration that allows maximum utilization of sputtered material onto the rotating substrates.

The Model 4410 System accepts up to three delta cathodes, or two cathodes and a heater. Delta magnetron targets can be either bonded or bolted to the backing plate. Some materials such as Ti/W must be metallurgically bonded.

As shown in Figure 3.4-21, the delta anode is water-cooled and the integral cathode cooling channel is centered on the erosion groove. The anode is operated in a bias mode where the chamber is kept cool because all current is collected at the water-cooled anode. Tapped holes are provided for target materials which can be bolted to the cathode face for quick changing; bolt heads are below the target surface in areas which are not sputtered. Materials that cannot be bolted may be bonded to the target backing plate.

Pole-pieces are arranged so there is one continuous erosion groove, a necessity for uniform power density. Magnets are ferrite and, therefore, not subject to demagnetization due to mishandling or passage of time and are external to the vacuum system. Variation of cathode-to-substrate distance is accomplished by raising and lowering the substrate table although the distance for best uniformity is set at the factory.

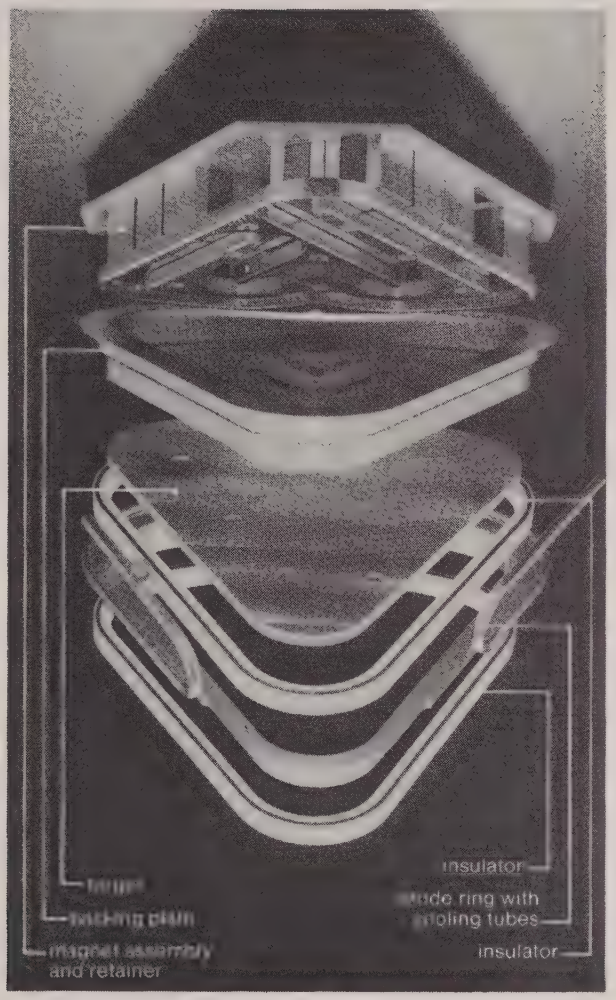


FIGURE 3.4-20 EXPLODED VIEW OF DELTA CATHODE ASSEMBLY

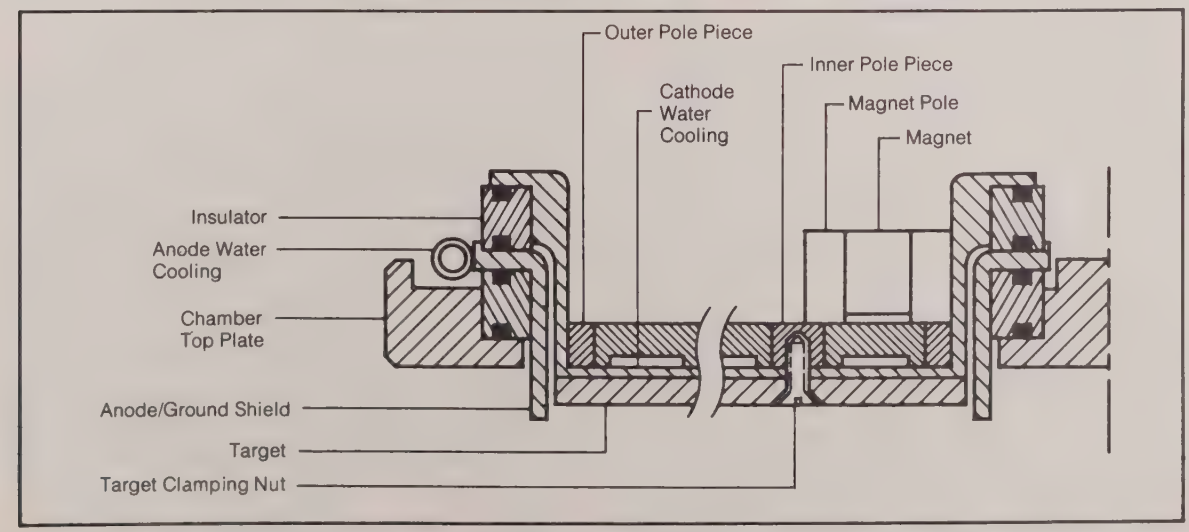


FIGURE 3.4-21 SCHEMATIC CROSS-SECTION OF DELTA CATHODE ASSEMBLY

After inspecting the seal surfaces on the insulator for damage, installing the pole pieces and magnets into the the backing plate, the procedure below should be followed to install the delta cathode assembly into the head (see Figure 3.4-22 through 3.4-27).

FIGURE 3.4-22 INSTALLING BOTTOM INSULATOR ON ANODE ONTO SPUTTER MODULE (DELTA)

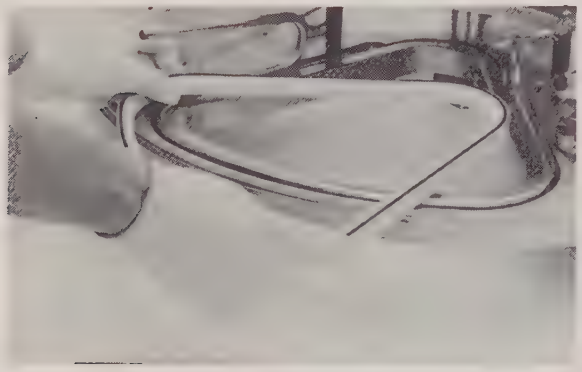


FIGURE 3.4-23 INSTALLING TOP INSULATOR ON ANODE (DELTA)

FIGURE 3.4-24 INSTALLING MAGNETS AND POLE PIECE ASSEMBLY INTO BACKING PLATE (DELTA)

FIGURE 3.4-25 INSTALLING CATHODE INTO SYSTEM WITH INSTALLATION TOOL (DELTA)

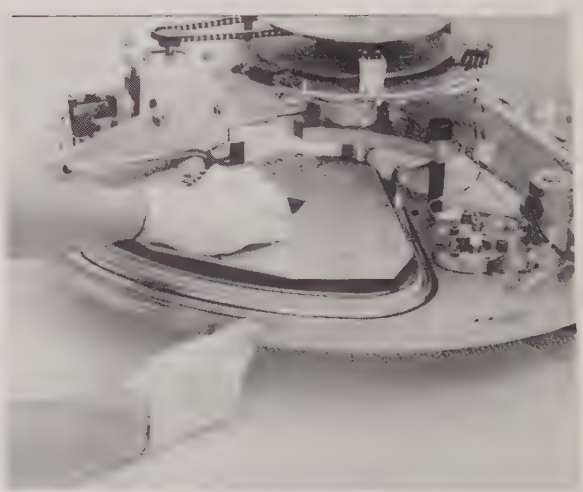


FIGURE 3.4-26 POSITION CATHODE BY PULLING OUT ON ASSEMBLY (DELTA)

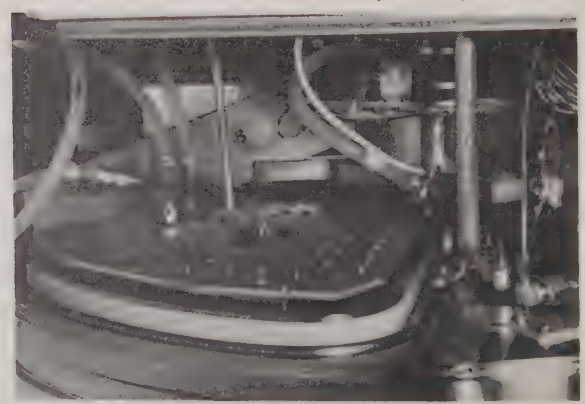


FIGURE 3.4-27 COMPLETED CATHODE ASSEMBLY WITH WATER AND DC MINUS (−) STRAP CONNECTED (DELTA)

1. As shown in Figure 3.4-22, place one insulator with O-rings on the bottom side of the anode and install this assembly into the sputter module cathode hole.
2. Place a second insulator with O-rings on top of the anode (see Figure 3.4-23).
3. After installing the magnets and pole pieces into the backing plate, (see Figure 3.4-24), insert the installation tool into the cathode assembly and double check that it is centered and firmly locked into place. Lift and install the cathode assembly into the second insulator on the anode. Remove tool after installation is complete (see Figure 3.4-25).
4. Using your hands, first pull back on the anode and then pull back on the cathode to properly fit cathode assembly into position (see Figure 3.4-26). Pump the vacuum system down and check leak rate to assure that it meets specifications and the seals are all properly seated and not leaking. An attempt to operate the system with a leak in this area may cause extensive failure of the complete cathode assembly and power supply.
5. Install water lines onto the cathode and the anode backing plate (see Figure 3.4-27).
6. Install electrical line (positive terminal of DC supply) onto anode and insure that the connections are tight.
7. Install stand off and power line onto cathode (negative terminal of DC supply) backing plate and insure that the connection is tight.

When the delta-cathode assembly is placed into the system and water lines connected, turn on the water supply and check for leaks after 30 minutes.

If no leak is evident initiate a load sequence with a bare pallet. After loading the pallet, turn the gas and power supply to ON and operate the target at a low power (1-2 kW) at 5-minute intervals and increase power as arcing subsides. New cathodes may arc for the first 10 to 15 minutes of operation. After initial burn-in, remove pallet and prepare the system for normal operation.

CAUTION

OPERATING AT A HIGH POWER WHILE ARCING IS PRESENT IN THE CHAMBER WILL CAUSE FAILURE AND DAMAGE TO THE SYSTEM.

3.4.4.5 Substrate Table Assembly

The Substrate Table Assembly consists of an aluminum annular table with a stainless steel ground shield. The substrate table is continuously rotated during processing either by an adjustable variable rotation speed control or a precision rotation speed control to provide even wafer to wafer coating uniformly.

The adjustable rotation speed control unit allows the substrate table rotation to be set from 1 to 10 rpm. The speed of the adjustable speed drive is not precise, but approximate at each setting. It is not intended for single pass deposition. (See Figure 3.4-28).

The precision table rotation speed control utilizes a DC series motor that has a feedback loop to precisely maintain a set speed. The range for this drive assembly is from 0.2 rpm (12 rph) to 10 rpm and is intended for single or multiple pass deposition. The precision drive is constant and repeatable in speed from run to run (see Figure 3.4-29).

Before loading the pallet, the substrate table must be set at INDEX by switching to GO TO INDEX position. After the pallet is loaded, the table will rise to either deposit or etch position, and rotation is enabled when START and GAS buttons are pressed simultaneously on the APC. When in the CONTINUOUS mode, the table will continue rotating as long as the ROTATE/STOP switch remains in the ROTATE position. The table will stop rotating when the ROTATE/STOP switch is pressed to the STOP position.

FIGURE 3.4-28 ADJUSTABLE SPEED CONTROL

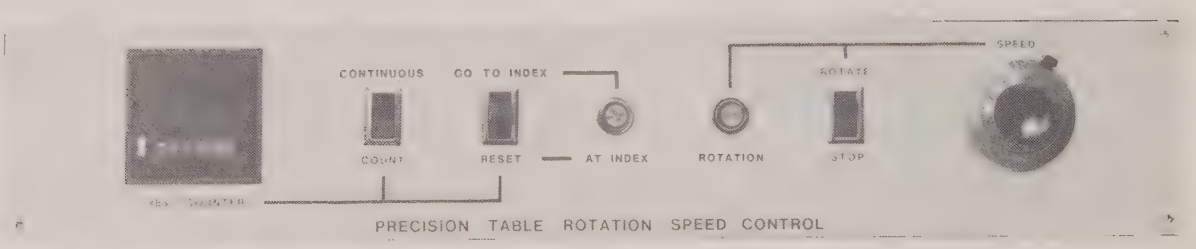


FIGURE 3.4-29 PRECISION TABLE ROTATION SPEED CONTROL UNIT

With the switch in the COUNT mode and the ROTATE/STOP in the ROTATE position, the substrate table will rotate to a preset number of revolutions. After each revolution, the INDEX light will illuminate and the counter will count-down one digit. The counter display will be between the last digit counted and the next digit to appear. When the counter reaches zero the table stops.

RF power and cooling water are transmitted by a coaxial line from the sputter module to the anode table through a side arm. This permits application of power to the table in the sputter etch and bias sputter modes. Integral copper tube cooling channels assure even distribution of cooling water. The assembly has a differentially pumped O-ring seal and can be easily removed for cleaning.

3.4.4.6 Shutter and Shaper Assembly for Round Cathodes

The two shutters in the Model 4410 system are a full circle shutter with a notch in it that is positioned over the sputtered target and a vane shutter that closes that notch when either pre-cleaning the target or sputter etching. The full circular shutter is made of a magnetic material so that it captures any flux lines. The vane shutter is made of molybdenum.

The shutter, as shown in Figure 3.4-30, interrupts the flow of material from the target to the substrate much like a camera shutter. A shaped insert in the 4410 shutter enhances the uniformity when the annular table is rotating during deposition. Since a substrate near the outer edge of the annular table moves more rapidly under the cathode than a substrate near the inner edge, it will have a thinner film deposited on it without a compensating factor. As shown in Figure 3.4-31, the round cathode has shaped insert has a wide aperture over the outer edge of the table and a narrow aperture at the inner edge to produce a uniform film. Only minor shaping is required with a delta cathode provided by blades on the full circle shutter.

The shutter height is adjusted as follows:

1. Raise the process head using the hoist.
2. Hold the shutter shaft with one hand. With the other hand, loosen the set screw in the clamp ring

above the table rotation gear above the top plate. Two people can more easily achieve this adjustment.

3. Adjust shutter to the desired position.
4. Tighten clamp ring.
5. Re-check shutter rotation and indexing.

FIGURE 3.4-30 SHUTTER ASSEMBLY

3.4.4.7 Plasma Igniter

The plasma igniter as shown in Figure 3.4-31, emits electrons from a highly negative hot filament to activate the plasma. When the sensor detects the absence of plasma after the RF power is turned on, it activates the plasma igniter. When the plasma ignites, the igniter shuts off. This eliminates the need to detune the system or raise the pressure when igniting the plasma.

3.4.4.8 Dark Space Shields (Round Targets)

The dark space shield, which surrounds the target and the cathode, prevents plasma being generated on the sides and the rear of the cathodes (see Figure 3.4-31).

The dark space shield focuses the discharge, provides grounding surfaces for the discharge, and prevents cross-contamination of targets by sputtered material, thus protecting the cathode/target from ion bombardment.

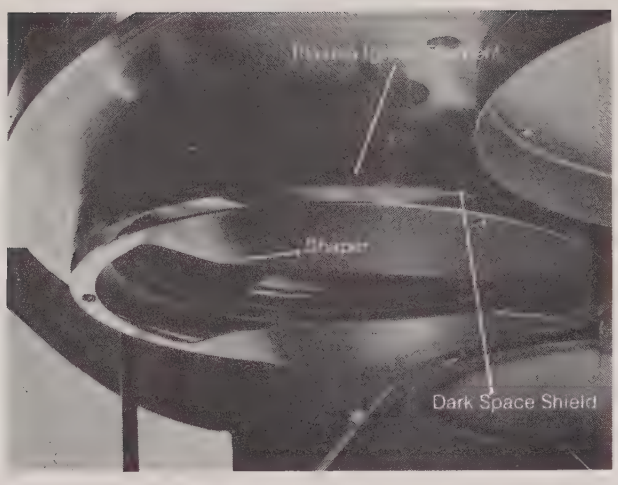


FIGURE 3.4-31 DARK SPACE SHIELD AND GROUND RINGS, PLASMA IGNITER, AND DEPOSITION UNIFORMITY SHAPER

3.4.4.9 Meissner Trap Assembly

The Meissner Trap is located inside the process chamber below the rotary substrate table (see Figure 3.4-32).

The Meissner Trap assembly serves as a high speed water pump when LN_2 is circulated through the assembly, to maximize water vapor pumping capability even when the high vacuum pump is throttled during the sputtering process. An optional quick purge system minimizes chamber venting cycle time by accelerated warming of the trap to prevent moisture condensation on the cold trap when it is exposed to atmosphere.

When the chamber is pumped down and the high vacuum gate valve is opened, the LN_2 flows through the Meissner Trap Assembly. A 3-position LN_2 switch (OFF, LN_2 continuous, and LN_2 timed) on the APC regulates the LN_2 flow into the Meissner Trap Assembly.

The design of the Meissner Trap Assembly allows it to be chilled by LN_2 or closed-cycle Freon refrigeration with special coil trap only. It has over 160 $in.^2$ of surface area and attains a pumping speed of more than 30,000L/s for water vapor, even with a very conservative 75% sticking coefficient. This allows the system to successfully deposit low resistivity, highly specular aluminum alloy films such as Aluminum-Silicon, or Aluminum-Silicon-Copper.

NOTE: Prior to opening the process chamber, the Meissner Trap should be warmed to prevent atmospheric moisture condensation on the cold surface. This may be readily accomplished by blowing clean dry air or dry nitrogen (N_2) at a pressure of not over 20 psi through the Meissner Trap for approximately 30 minutes.

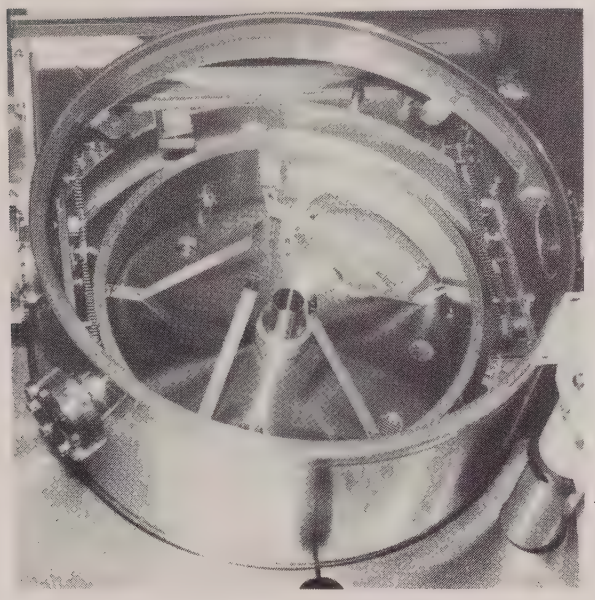


FIGURE 3.4-32 FULL FLOOD MEISSNER TRAP ASSEMBLY AND SPUTTERING SHIELDS

3.4.4.10 Plumbing Purge Control

The plumbing purge control, as shown in Figure 3.4-33, is used to allow the operator to vent the system by blowing out all the water lines and the LN_2 in the Meissner Trap Assembly independently. After the cooling water and the LN_2 are turned off, the plumbing purge control is used to either clear the water lines or Meissner Trap by forcing dry N_2 through the lines.

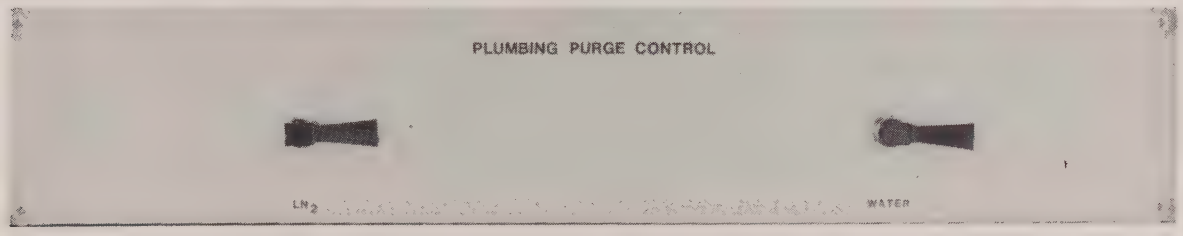


FIGURE 3.4-33 PLUMBING PURGE CONTROL

3.4.4.11 Digital Clock Timers (DCTs)

The Digital Clock Timer (DCT) provides an accurate and reliable means of timing sputtering operations (see Figure 3.4-34). At the end of the designated period, the timer stops the operation automatically, without requiring additional operator attention.

The DCT operates in two modes. In the automatic mode, it starts automatically when either the RF power button on the system control panel or the DC button on the DC magnetron power supply is activated. In the manual mode, it is started manually by depressing its own front panel switch. It is possible to switch modes at any point in the process. It is also possible to change the time period at any point.

In either mode, when the preset time has run out, the timer automatically turns off the RF power to the sputtering module. Then, the timer automatically resets itself to repeat the previous timing shown on the digital readout, unless the operator changes it.

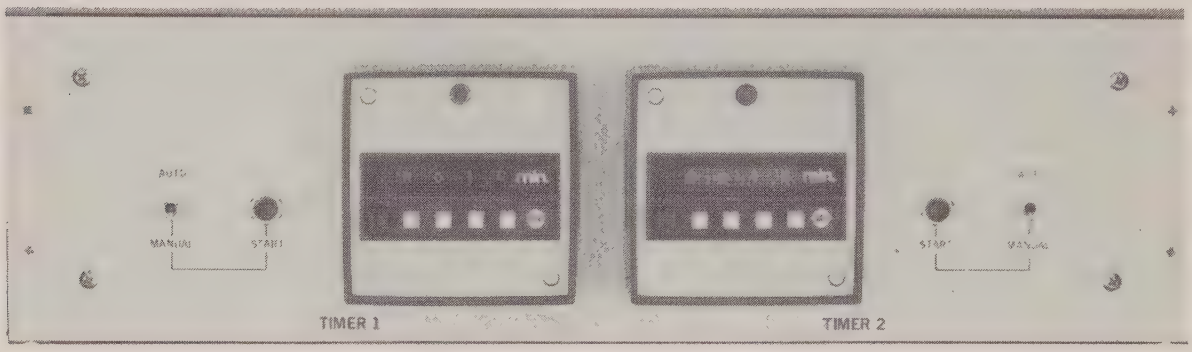


FIGURE 3.4-34 DIGITAL CLOCK TIMERS (DCTs)

The DCT is connected in series between the power supply and processing head as shown in Figure 3.4-35. If the power stabilizer is included in the system, it must be placed between the timer and processing head.

The following steps describe the operation of the DCT.

1. Set the desired time with the white pushbuttons while pressing the blue pushbutton.
2. Turn on the RF power, tune and adjust the power level as desired, and open the shutter if necessary. In the AUTOMATIC mode, RF power will remain on for the time set on the timer, starting from the point when the RF is turned on.
3. In the MANUAL mode, press the START button. The RF power will remain on for the time set on the timer, starting from the point when the START button was pushed.
4. At the end of the time period the operator may return to step 1 if a different time is desired, or step 2 if the same time is to be used.

It is possible to switch modes at any point in the process. It is also possible to reset or change the time period at any point with the white pushbuttons while keeping the blue pushbutton pressed.

When the blue reset button is pushed after the timer has started, it does not affect either the instantaneous switches, (which have transferred and remain transferred) or the delayed switches (which have not yet transferred). It simply stops the digital wheels and resets them back to the numbers they showed when the cycle started. If the start circuit remains closed, the timer will immediately begin a new cycle when the reset pushbutton is released. In effect, this one cycle would then be extended to include (1) the elapsed time in the interrupted cycle; (2) the period while the reset button was held in; plus (3) the new time cycle set on the timer.

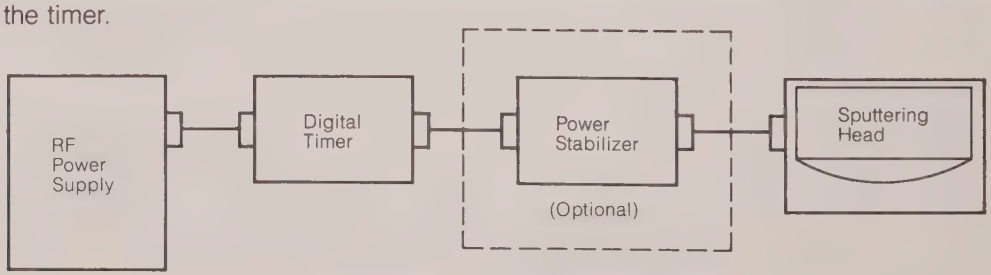


FIGURE 3.4-35 DCT CONNECTION

3.4.4.12 Servo-Match Automatic Tuning and Control

Power from the RF generator is impedance matched to the targets and plasma by means of an impedance matching network built into the sputtering head assembly. This network adjusts the real component of the impedance with an air core transformer in which the primary-to-secondary coupling is varied by moving the primary coil in or out of a coaxial relationship to the secondary coil. This air core transformer, referred to as the load link, is water-cooled and provides DC isolation between the matching network and the RF generator. The imaginary component of the impedance is adjusted by the variable tuning capacitor.

The servo match continuously and automatically monitors the phase relation between current and voltage in the transmitter line and adjusts the sputtering module impedance to provide optimum tuning. It holds the system in tune even if the sputtering mode (sputter deposit, bias sputter, or sputter etch) is changed or if target materials, power level, or cathode-to anode spacing are varied. Slight adjustment of the load position is sometimes required when the bias level is changed in the bias sputter mode.

Servo-Match Automatic Tuning consists of three major units; (1) plasma igniter; (2) load servo; and (3) phase detector and tune servo.

The plasma igniter emits electrons from a highly negative hot filament to activate the plasma (see Figure 3.4-31).

The load servo is activated automatically when a target is selected. It adjusts the moveable inductor link to values preset for each operating mode and target. Preset values may be easily changed if a new target is introduced or the system otherwise modified.

The tune servo is controlled by a phase detector which examines the phase relationship between voltage and current in the transmisson line from the RF generator to the sputtering module to determine whether optimum tuning exists. If the tuning is not within a narrow band around the optimum, tune servo adjusts a variable capacitor until optimum tuning is attained. Initial tuning after power is turned on usually takes only a few seconds. The circuit then continuously tunes the system to minimum reflected power.

The Servo-Match Control shown in Figure 3.4-36 can be operated in either automatic or manual modes. In the automatic mode of operation, the network will match RF generator output automatically. In the manual mode, the matching impedance can be changed by means of TUNE and LOAD switches located on the process chamber front panel.

FIGURE 3.4-36 4410 SERVO-MATCH CONTROL

The Servo-Match Control consists of two functional parts:

1. Load Adjust Circuitry—provides the amplitude ratio adjustment and operates semi-automatically. The level has to be readjusted whenever there is the need, e.g., change of target material or sputtering pressure. However, once set for a particular target and process, it will automatically readjust for that level whenever that target is selected. The small servo-loop consists of an error-detecting sensor (a rheostat coupled mechanically with the link). Located on the front panel are potentiometers for load adjust presetting. The controller, with two output relays, drives the link servo-motor.
2. Tune circuitry—provides the phase ratio adjustment and operates automatically. The servo-loop consists of an RF sensor, phase detector, analog/logic convertor, logic circuitry and two outputs. This signal drives the tuning capacitor servomotor. The RF sensor is located on the rear panel and has two RF connectors labeled POWER IN and POWER OUT and a variable capacitor (C14), as shown in Figure 3.4-37, for adjusting the reference voltage phasing.
3. The phase detector circuit is to detect the phase shift mismatch between the RF generator and the target, and to produce an output of proper polarity to tune an impedance matching network. The detector is factory aligned and realignment will be necessary only if defective parts are replaced in the servo-match circuits (see Figure 3.4-37 for Servo-Match adjusting procedure). However, if any doubt exists, the customer should contact the Perkin-Elmer PPD Service Group before attempting further adjustment or servicing.

Before initial turn on, the cables should be secure and the MODE switch set to MANUAL. After establishing the proper argon pressure in the chamber, RF power can be applied (set at a low level). A plasma should be observed. The system must be matched manually first (by the means of LOAD and TUNE switches) to minimize the reflected power reading. If low enough reflected power has been reached, slowly increase the forward power to process value while keeping reflected power low. Switch into the AUTO mode and adjust the LOAD ADJUST, one or the other direction, to minimize REFLECTED POWER and wait 3 to 5 seconds between each adjustment. The LOAD control must be readjusted if the target material is changed and, in the BIAS mode if table spacing, pressure, or power are changed.

3.4.4.13 Deposition Uniformity

In the Model 4410 System the use of circular DC or RF magnetron cathode targets create a circular, symmetrical deposition pattern in which uniformity is achieved by "shaping" the vapor flux. In normal operation, substrates are placed on the annular substrate table and continuously rotated under the target while deposition is in progress. Figure 3.4-38 illustrates the relationship of substrates located at different radial distances from the rotational axis and the target. With the annular table rotating continuously, a substrate near the outer edge (R2) will have a thinner film deposited on it than the substrate near the inner edge (R1), thus affecting deposition uniformity.

This nonuniform deposition pattern is corrected by simply placing a shaped insert which has a wide aperture over the outer edge of the table and a narrow aperture at the inner edge, thus producing a uniform film.

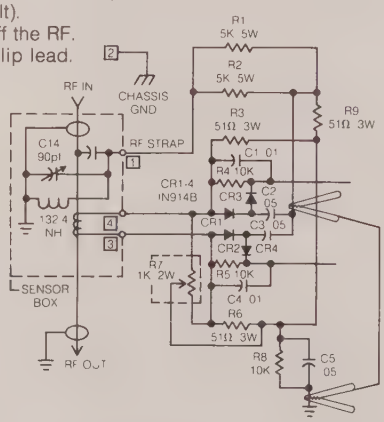
Delta cathode targets do not require shaping apertures, however, a modified shutter opening is used to trim for high uniformity. The shapers used with the circular RF or DC cathodes can be easily changed or cleaned whenever the chamber is vented.

Minimum performance parameters of the Model 4410 System are:

Uniformity	±7%
Uniform deposition region	6-inch band of annular pallet (¾"–6-¾" from I.D.).
Substrate target distance	2¼ inches
Operating pressure	5–15 Torr.

I. PHASE DETECTOR BALANCE ADJUSTMENT
(SCHEMATIC D221-423-300
D221-479-000)

a. Connect clip lead from intersection R1 (5K) and R9 (51 ohms) to nearby ground—R8 (10K).
b. Connect scope (or high impedance meter) to external test point.
c. Switch into manual mode and turn on RF power to about 1/3 full power.
d. Manually tune system.
e. Adjust R7 (pot 1K) for zero volts at test point. NOTE: You must be able to change the test point voltage + or – with the pot.
f. Change the RF power 0 to full, test point voltage has to stay around zero. (should not deviate more than ± 0.5 volt).
g. Turn off the RF. Remove clip lead.



II. SENSOR ADJUSTMENT

a. All steps in the ETCH mode first, then check other modes.
b. See I-b.
c. See I-c.
d. See I-d.
e. Adjust capacitor C14 (on the sensor box) to cause test point voltage to cross zero volts. This will occur at TWO (2) different settings of the capacitor. (Higher capacity clockwise and lower capacity counterclockwise). If not, two sensor outputs have to be "swapped" (to 3 and 4). Adjust the capacitor to the setting in which the test point voltage will cross zero at higher capacity. (Turn the capacitor clockwise).
f. Check if you picked up the right one: move the "TUNE" control both directions, while observing the test point voltage.

The voltage has to change in one or the other direction (depends on the "TUNE" Control) but it has to cross zero *ONCE* only! Also must not enter ±0.25V region more than ONCE. If you get TWO (2) zero crossings, go back to II-3, then repeat II-f. NOTE: If you are not able to get ***one*** enter only into the deadband (±0.25V region), check the sensor to sputterhead cable length. It has to be *6 ft 1 inch.* Difference more than ±½ inch in length will cause to enter into the deadband in etch mode. Correct the cable (replace) and repeat sensor adjustment.

NOTE: *Shorter* cable will cause entry into 0.25V region from – polarity of the test point voltage.

Longer cable will cause entry into 0.25V region from + polarity of the test point voltage.

FIGURE 3.4-37 SERVO-MATCH ADJUSTMENT PROCEDURE

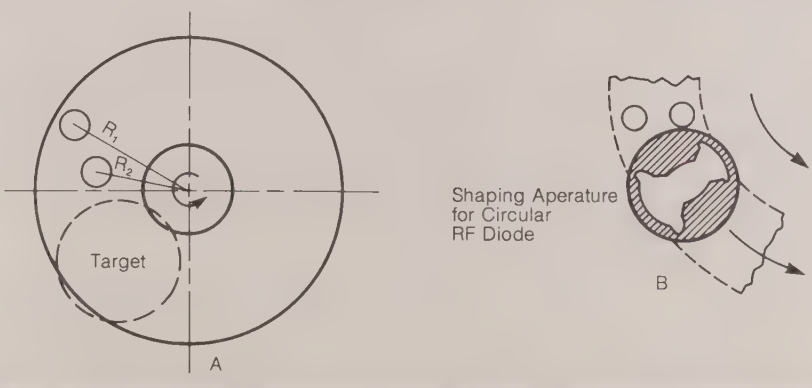


FIGURE 3.4-38 RELATIONSHIP OF SUBSTRATES LOCATED AT DIFFERENT RADIAL DISTANCES FROM ROTATIONAL AXIS AND CATHODE

3.5 OTHER INSTRUMENTATION

Several additional features and instrumentations are available for the Model 4410 System. See your Plasma Products Division marketing representative for other optional features.

3.5.1 Manual Power Stabilizer

The manual Power Stabilizer is a device which provides regulation of the RF power level delivered to a sputtering chamber. Specifically, constant power will be maintained for RF sputtering and etching processes despite considerable variations in AC line voltage, gas pressure, work characteristics, and temperature. This device, when used with automatic RF tuning, ensures steady load power regardless of tuning variations in either the associated RF generator or in the sputtering module. All operator controls and indicators are located on the front panel, and the electrical connections are made at the rear panel. Single-phase, 115 VAC power is converted to DC voltages of +15 and −15V for operating the solid-state integrated circuits.

Figure 3.5-1 shows the physical location of all controls and indicators used on the manual Power Stabilizer. The names and functions of these controls and indicators are described in Table 3.5-1. The two basic modes of operation are stabilization ON and OFF. A description of each of these modes follows:

1. Stabilization On—In this mode of operation the power level is regulated and controlled by a potentiometer on the front panel of this stabilizer. After setting the MANUAL POWER ADJUST potentiometer to a desired position, RF power to the sputtering head can now be adjusted to any desired operation.
2. Stabilization OFF Mode—In this mode of operation there is no stabilization of the RF power. The RF power level is manually controllable by the RF POWER ADJUST potentiometer on the system meter panel. Note: the RF POWER meter on the front panel of the Programmable Power Stabilizer is active only when the STABILIZATION switch is in the ON position. This is true for both automatic and manual modes of operation.

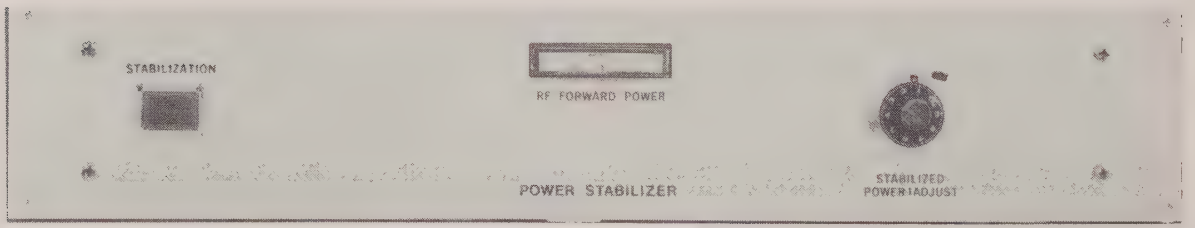


FIGURE 3.5-1 MANUAL POWER STABILIZER CONTROLS AND INDICATORS

TABLE 3.5-1
CONTROLS AND INDICATORS (MANUAL STABILIZER)

NAME	FUNCTION
STABILIZATION-ON/OFF Pushbutton/indicator	Used for turning on and off the Power Stabilizer. (In OFF position, RF power is manually controlled.)
RF POWER Meter	Used to indicate the amount of forward RF power being applied to the system.
STABILIZED POWER ADJUST Ten-turn variable potentiometer	Used for adjusting stabilized power.

3.5.2 Programmable Power Stabilizer

The programmable power stabilizer is an option to the 4410 Sputtering System. For technical details, please refer to Appendix A.

3.5.3 Substrate Heating

For most systems, a process chamber heater is available to provide substrate heating before and during deposition. In some cases, this can enhance film adhesion and provide control of grain size.

3.5.4 Partial Pressure Analyzer

The Partial Pressure Analyzer (PPA), as shown in Figure 3.5-2, is a laboratory type cycloidal mass analyzer utilizing crossed magnetic and electrostatic fields. The PPA measures partial gas pressures by selectively detecting the individual mass/charge ratios that constitute the gas. The PPA is capable of measuring masses in the range of 2 to 100 atomic mass units (amu). The effective operating range of the analyzer is from 2 x 10^{-4} Torr to ultra-high vacuum. The PPA is used primarily for partial and total pressure measurements, leak detection, gas analysis, and out-gassing studies. Its applications include areas where reliable quantitative information is essential, such as failure analysis of sputtering gas analysis. The operation of the PPA, if it is part of a specific customer order, is provided in Appendix F.

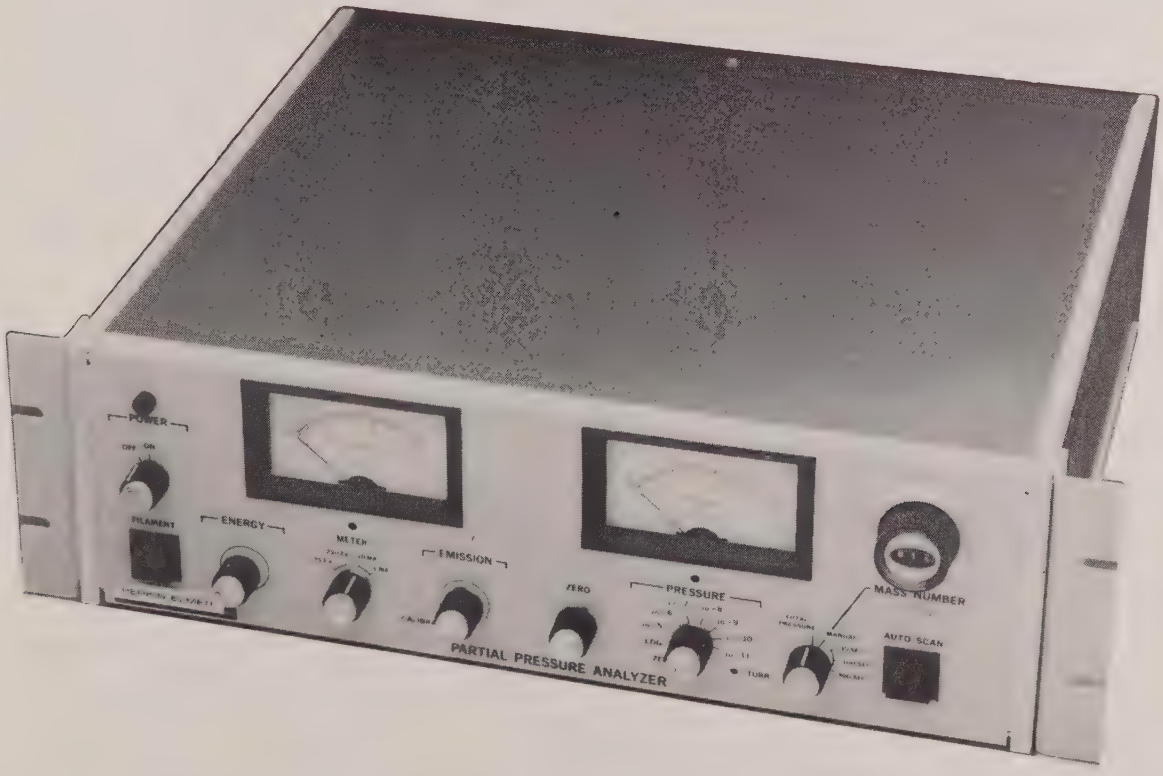


FIGURE 3.5-2 PARTIAL PRESSURE ANALYZER

3.5.5 Load Lock Heater (100°C)

WARNING

HEATER MUST BE TURNED OFF BEFORE RF POWER IS TURNED ON.

The Load Lock heater power supply consists of a WATLOW time proportional temperature controller with auxiliary set points, a PAYNE zero crossing triac power controller, power switch/circuit breaker, indicating lamp for heater power, a quartz lamp heater assembly and a primary power and logic controlling relays to interface the WATLOW control logic with the modified Load Lock Control unit.

The 100°C Load Lock heater system is designed to provide a means of heating a pallet with substrates prior to transfer into the processing chamber. The system will automatically turn on upon initiation of an automatic LOAD command from the modified Load Lock Controller. After meeting preset temperature-time settings, the Load Lock heater power supply will signal the Lock Controller to continue normal LOAD operation and the pallet will transfer into the chamber to complete processing. The Load Lock heater was designed to heat the pallet to 100°C, while the Load Lock is continuously pumped. A visual readout of the actual temperature is provided by a panel meter on the WATLOW temperature controller. The operating sequence of the Load Lock heater is as follows:

1. Turn on the power switch on the front panel of the power supply. Indicator lamp on the front panel will light to indicate power supply is ready to operate upon automatic command of LOAD from the Load Lock Control unit.
2. Select the temperature by adjusting the multi-turn potentiometer to the desired temperature setting (100°C).
3. Close the Load Lock door by depressing the two pushbutton switches until the motor drive stops.

NOTE

THE POWER SUPPLY CIRCUIT WAS DESIGNED TO OPERATE IN THE AUTO MODE OF THE LOAD LOCK CONTROLLER. THE POWER SUPPLY WILL TURN ON WHENEVER THE ROUGHING VALVE ON THE LOCK OPENS.

4. When the lock roughing valve opens, the modified Load Lock Controller circuit will reset and latch on the relays in the power supply and turn on the Load Lock heater.
5. The relays in the modified Load Lock Control will inhibit the trip point logic on the Load Lock Controller preventing the pallet from transfering while the heater is on, and will cycle the roughing valve (open or close) to maintain the trip point.
6. The heater will heat the pallet until the thermocouple reaches the preset termperature limit.
7. When both the trip point 100 to 200 microns or less and temperature (100° C) reach preset limits, the roughing valve will close, the lock valve will open, and the pallet will transfer into the process chamber. (The ALARM set point in the WATLOW is the actual temperature set point. The knob control should be set slightly higher than the ALARM to clear the proportional band.)
8. When the lock valve closes, the heater will automatically turn-off.

CAUTION

THE HEAT SINK OF THE TRIAC CONTROLLER IS AT FULL LINE POTENTIAL. ADJUSTMENTS OR MAINTENANCE SHOULD ONLY BE PERFORMED BY QUALIFIED PERSONNEL. COVERS SHOULD BE KEPT IN PLACE AT ALL TIMES TO PREVENT HAZARD OF PERSONAL CONTACT OR FOREIGN OBJECTS FALLING ACROSS HIGH VOLTAGE POINTS.

The next energizing of the lock control heater will occur upon the next automatic load sequence. The WATLOW temperature controller used in the heater power supply is a time proportional output unit. In this application we choose to adjust the proportional band and time to allow the PAYNE controller to be continuously on during the heat cycle. This is accomplished by adjusting the temperature set point (large knob) above the desired process trip point. For example, if a desired temperature of 100°C is to be set, the alarm adjust trip point (screw driver adjustment on WATLOW front panel) will be set to 100°C. The temperature control set point (large knob on the WATLOW) would be set to some higher temperature, above the proportional band. (To heat to 100°C, the WATLOW set point should be set at 120°C).

3.5.6 Microprocessor Process Controller

Refer to Appendix B for a full technical description of the Microprocessor operation.

SECTION 4

OPERATOR'S GUIDE

4.1 INTRODUCTION

The Model 4410 Sputtering System, as shown in Figure 4.1-1, contains several units which control the production during a sputtering process. The operator is responsible for the preparation of the system for operation, cleaning the system, loading and unloading, and maintaining the parameters set by the system engineer. After each shift, he should clean and ready the system for the next operator.

The following sections will explain the functions and the operation of the Model 4410 System. Operators should read these instructions carefully and become familiar with the tasks they are to perform and the controls they will use, before attempting to operate the system.

CAUTION

THE MODEL 4410 SYSTEM IS DESIGNED WITH SAFETY FEATURES TO PROTECT THE OPERATOR DURING SYSTEM OPERATION. IF AN ABNORMAL SITUATION IS OBSERVED, TURN OFF THE RF OR DC POWER SUPPLY AND NOTIFY THE SYSTEM ENGINEER IMMEDIATELY.

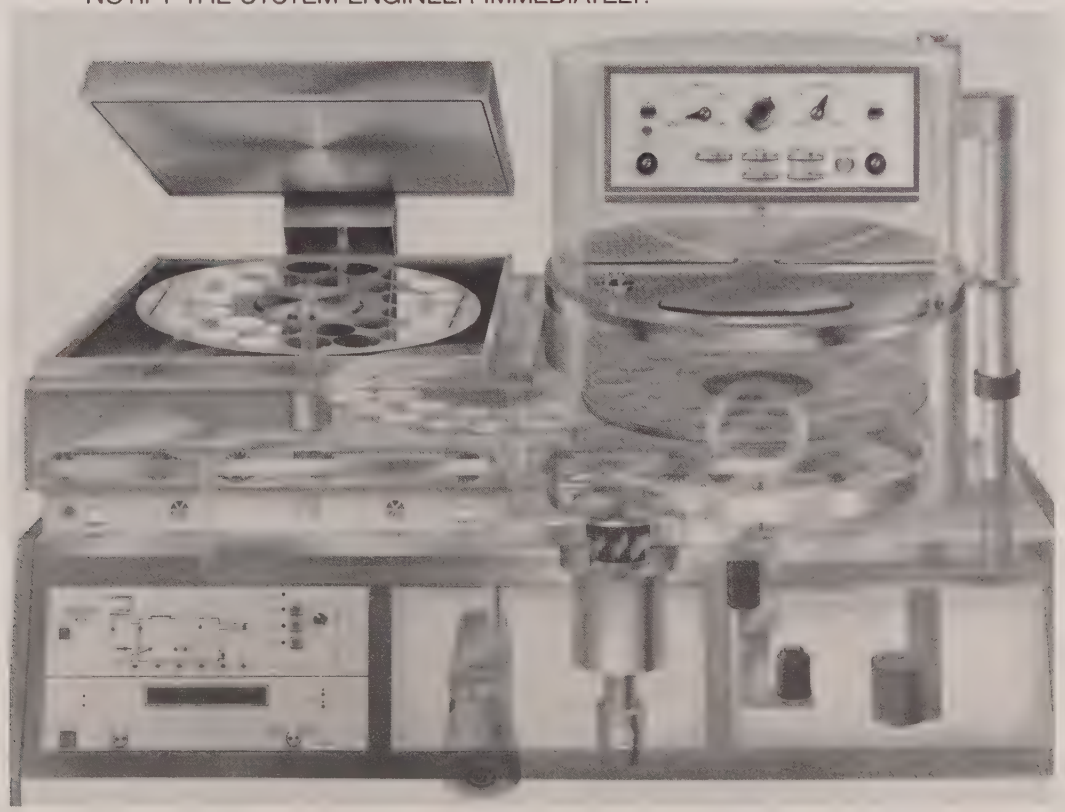


FIGURE 4.1-1 PERKIN-ELMER SPUTTERING SYSTEM

4.2 GENERAL DESCRIPTION

The Model 4410 System is used primarily to apply very thin film of certain materials to the surface of substrates (DEPOSIT MODE). It may also be used to simultaneously etch or sputter the substrates in order to provide excellent step coverage or to provide low stress films (BIAS MODE), or to remove surface contamination or thin layers from the substrate surfaces (ETCH MODE). In the DC Mode, the process is essentially similar to DEPOSIT MODE. However, instead of RF power, DC power is applied to the target. In DEPOSIT Mode, the coating material (such as silica) is taken from a "Target" and transferred to the substrates in a vacuum chamber by means of radio-frequency (RF) energy. In ETCH Mode, the RF energy takes material from the substrates and deposits it either on a shutter plate, which swings into place for this purpose, or on a catcher plate installed in place of the target. The whole process—including loading a pallet full of substrates into the Load Lock, then transferring it into the vacuum chamber, pumping the condensable gases out, coating or etching, and removing the substrates—can take from a few minutes to several hours. Most of this time the machine operates automatically, and requires only that the operator be nearby to respond to any malfunction alarms.

4.3 SPUTTERING PROCESS

Sputtering is a process by which atoms are dislodged from one material and deposited as a thin layer on another material. In DEPOSIT MODE the material is taken from a "Target" and coated onto the substrates being treated; in ETCH MODE it is removed from the substrates and collected on a shutter or catcher plate. The pallet of substrates and the target or catcher plate face each other a few inches apart in a sealed chamber from which most of the air has been removed, so that material atoms can travel without hitting air molecules. Atoms are dislodged from the target or substrates by bombarding them with electrically charged ions of a gas (usually argon), which flows at low pressure through the chamber. The gas ions give up their momentum to the atoms, breaking them loose from one surface and allowing them to travel across the gap to the other surface. At this time the ions lose their electrical charge, becoming gas atoms again. Many of them are then re-ionized by secondary electrons, which are ejected when atoms are broken loose from the surface of the material.

If the material being transferred is an insulator, emitting these secondary electrons will cause a positive charge to build up on its surface. This is removed by reversing the electrical polarity frequently to attract free electrons. Polarity reversal is accomplished by using 13.56 MHz RF power to drive the sputtering process.

In "bias" depositing, most of the power is applied to the target, but some is also applied to the substrates. This causes a "back and forth" action, which in some applications results in a higher quality coating.

Taken together, the target and substrates act like a giant diode. The negative electrons, being lighter, are more easily captured during the positive half cycle of the RF voltage than are the positive ions during the negative half. Thus a negative voltage collects on the material being bombarded. Measuring this voltage (as SUBSTRATE BIAS or TARGET BIAS on the Meter Panel) indicates how active the material transfer process is.

4.4 OPERATING CONTROLS

A number of adjustments are provided on the machine to control such variables as the thickness and quality of the coating (or etching) and the efficiency of the transfer process. These adjustments should not need changing during normal production usage of the system. They are described in Section 3, "System Engineer's Guide."

The controls that the machine operator will need are located on the following controllers:

1. Load Lock Control
2. Automatic Pumpdown Controller
3. Digital Gauge Controls
4. Servo Match Control
5. Auto Regeneration Controller
6. Power Supplies (RF and DC)

4.4.1 Load Lock Assembly and Control

The Load Lock Control permits loading, pumpdown, and preheating the substrate material in the Load Lock before it is transferred into the main processing chamber. The Load Lock is mounted on the left side of the chamber and rests on top of the cabinet. The Load Lock Control, as shown in Figure 4.4-1, is located directly below the lock door switches below the Load Lock assembly.

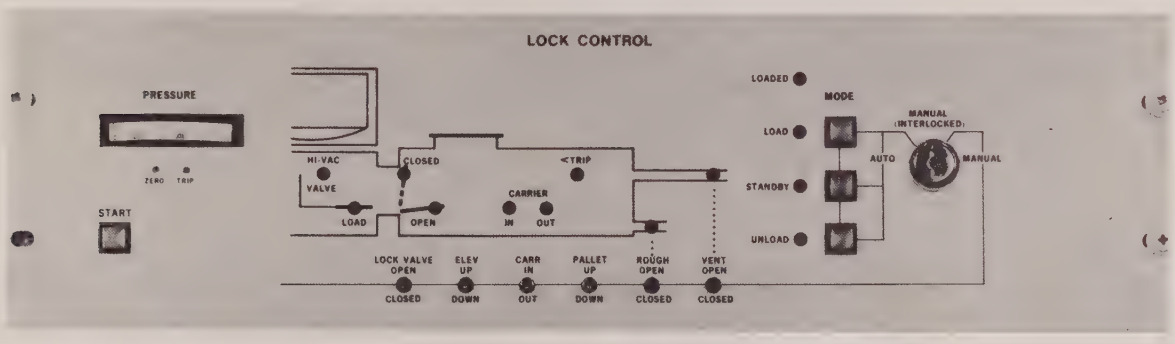


FIGURE 4.4-1 LOAD LOCK CONTROL

After placing a pallet on the self-aligning elevator, both lock door switches on the narrow panel below the Load Lock should be depressed until the Load Lock cover closes and the drive motor stops.

The Load Lock Controller can be operated either in MANUAL INTERLOCKED or AUTO modes by selecting the desired mode with the key switch. The lock control panel displays a schematic diagram of the system, with illuminated LED's to indicate the status of various system elements. This allows the operator to keep track of the process as it is running. Table 4.4-1 describes the Load Lock control panel features.

TABLE 4.4-1

LOAD LOCK CONTROL SWITCHES

CONTROL SWITCH	FUNCTION CONTROLLED
MODE AUTO/MANUAL INTERLOCKED/MANUAL (three-position key switch)	Setting this switch in the AUTO position enables the pushbutton controls described in this table. Selecting the MANUAL INTERLOCKED mode enables the panel toggle switches with all interlocks functioning. Selecting MANUAL and switching the rear panel switch to INTERLOCK DEFEAT permits operation of all functions independently for maintenance purposes.
WARNING DO NOT LEAVE THE REAR PANEL TOGGLE SWITCH IN THE INTERLOCK DEFEAT POSITION. INADVERTENT OPERATION IN THIS MODE CAN RESULT IN EXTENSIVE SYSTEM DOWNTIME CAUSED BY VENTING TO ATMOSPHERE OR OTHER SUBSTRATE DAMAGING CONDITIONS AS WELL AS DAMAGE TO THE SYSTEM.	
LOADED (Indicator) Load) Standby) Unload)	This indicator functions only if the AUTO Load sequence has been used. These switches, when pressed simultaneously with the START button, automatically initiate the appropriate function. In the STANDBY Mode, the cycle is temporarily discontinued and can be restarted by pressing either START and LOAD or START and UNLOAD, depending on cycle.
VENT VALVE	Controls opening and closing of the lock vent valve.
ROUGH VALVE (OPEN/CLOSE)	Controls the status of the Load Lock roughing valve.
PALLET UP/DOWN	Positions the substrate table in processing chamber.
CARRIAGE IN/OUT (three-position switch)	Controls the transport drive mechanism. Center Position stops mechanism.
ELEVATOR UP/DOWN	Raises and lowers the pallet for loading and unloading.
LOCK VALVE OPEN/CLOSE	Opens and closes interchamber door between load lock and process chamber.

TABLE 4.4-1 (cont'd)

CONTROL SWITCH	FUNCTION CONTROLLED
PRESSURE ZERO/TRIP	Potentiometer adjustments located just below the Lock pressure meter. The ZERO is set by first roughing the Lock, then opening the interchamber valve door to permit high vacuum pumping of the Lock. When the Lock pressure is 1×10^{-4} Torr or lower, the meter is set to read zero, using the potentiometer labeled ZERO. To set the pressure at which the Lock roughing ends and the interchamber valve door opens, rough the Lock chamber to the desired pressure then adjust the potentiometer labeled TRIP until the trip indicator illuminates. This trip point is set at the factory at 100 microns. (This pressure assures speed in pumping and minimizes oil backstreaming from roughing pump.) The TRIP point on the Lock Controller must always be set at a lower pressure than the TRIP point in the APC.
	CAUTION CARE MUST BE EXERCISED WHEN OPERATING IN THE MANUAL MODE SO THAT TABLE AND CARRIAGE LOCATIONS ARE KEPT CLEARLY IN MIND. IF THE PALLET IS ON THE TABLE AND THE TABLE IS LOWERED, THE CARRIAGE CAN BE TRANSPORTED INTO THE CHAMBER OVER THE PALLET. RAISING THE TABLE WOULD LIFT THE CARRIAGE OFF THE TRANSPORT MECHANISM AND IT MIGHT BE NECESSARY TO VENT THE SYSTEM TO MAKE THE TRANSPORT MECHANISM OPERABLE AGAIN.
Lock at ATM (Indicator)	Located on the water flow switch/lock door panel. When illuminated, it indicates Load Lock is at atmospheric pressure.

The automatic load sequence operates as follows:

1. When the lock door is fully closed, the roughing valve opens and the Load Lock is roughed to the preset trip point pressure.

NOTE

THE TRIP POINT IS SET AT ANY PRESSURE LEVEL FROM 10 TO 500 MICRONS BY A POTENTIOMETER LOCATED JUST BELOW THE METER ON THE LOCK CONTROL PANEL. HOWEVER, TO MINIMIZE ROUGHING PUMP OIL BACKSTREAMING, 100 MICRONS SHOULD BE USED.

2. The roughing valve closes, the interchamber valve door opens, and the pallet carriage transports the pallet into the processing chamber.
3. When the carriage is fully inserted, the table is raised, lifting the pallet off the carriage.
4. After the table is fully elevated, the carriage retracts into the Load Lock and the interchamber valve door closes.
5. The processing can now begin.
6. The pallet is unloaded from the process chamber in a reverse manner. Both the load and unload operations are described in detail in Section 4.4.2.

4.4.2 Load Lock Operation

Detailed instructions for operating the 4410 Load Lock in the manual and automatic modes are given separately below. Operators who have little or no knowledge of Load Lock functions should become thoroughly familiar with this and the preceding sections of the manual before operating the lock.

4.4.2.1 Manual Operational Sequence

NOTE

BEFORE OPERATING IN THE MANUAL MODE, PLACE ALL SWITCHES IN THE OFF POSITION.

1. Set the LOCK VALVE switch to CLOSED.
2. Put the Lock controller key switch in the MANUAL INTERLOCKED position.
3. Open the Lock door using both actuating switches located below the Load Lock.
4. Set the PALLET switch to DOWN position.
5. Set the CARRIAGE switch to OUT.
6. Set the ELEVATOR switch to UP.
7. Place the pallet on the elevator.
8. Set the ELEVATOR switch to DOWN. This will lower the pallet onto the carriage.
9. Close the lock door using both actuating switches. Be sure the motor drive stops by itself.
10. Set the VENT VALVE switch to close.
11. Set the ROUGH VALVE switch to OPEN. This will cause the mechanical pump to rough the Load Lock.
12. Pump the Lock until the trip point is reached. This is indicated by the TRIP light on the Lock Control panel.
13. Set the ROUGH VALVE switch to CLOSE. This will terminate roughing and isolate the mechanical pump from the Load Lock. (Open Foreline valve if system is pumped by Turbomolecular pumps.)
14. Set the LOCK VALVE switch to OPEN. This causes the interchamber valve door to open.
15. Set the CARRIAGE switch to IN. This causes the pallet transport mechanism to move the carriage into the sputtering chamber.
16. Set the PALLET switch to UP. When the CARRIAGE IN light comes on, the anode/table will rise and pick up the pallet from the carriage.
17. Set the CARRIAGE switch to OUT. The carriage then withdraws into the Load Lock.
18. Set the LOCK VALVE switch to CLOSE. The interchamber valve door closes to isolate the Lock chamber from the sputtering chamber.

4.4.2.2 Manual Unload Sequence

If the TRIP indicator is not illuminated, set the ROUGH VALVE switch to OPEN to reduce the Lock pressure to the trip point. (If turbomolecular pump is used, close the foreline valve first.) After reaching TRIP point proceed with the following.

1. Set the ROUGH VALVE switch to CLOSED (if it was opened).
2. Set the LOCK VALVE switch to OPEN to open the interchamber valve door.
3. Set the CARRIAGE switch to IN (table must be in UP position).
4. When the carriage indicator labeled IN illuminates, set the PALLET switch to DOWN.
5. Set the CARRIAGE switch to OUT after the pallet is completely lowered onto the carriage.

6. When the carriage indicator labeled OUT illuminates set the LOCK VALVE switch to CLOSED.
7. When the indicator which is labeled CLOSED illuminates set the VENT VALVE switch to OPEN.
8. When the LOCK AT ATM indicator illuminates, the Lock door may be opened by depressing both actuator switches.
9. Set the ELEVATOR switch to UP.

4.4.2.3 Automatic Operating Procedure

The following describes the procedure of using the Load Lock in the automatic mode.

1. The transport carriage must be in the OUT position.
2. The interchamber valve door must be closed.
3. The lock chamber must be vented to atmosphere.
4. The lock door must be open.
5. The processing chamber must be under vacuum with the high vacuum valve open.
6. Place the Loaded substrate pallet on the elevator.
7. Use both door actuating switches to close the Lock door. The elevator will automatically lower the pallet onto the carriage and the LOAD indicator will illuminate on the Lock control panel. Allow the Lock door drive to run against the limit switch and stop of its own accord.
8. The LOADED indicator will illuminate when the load sequence is complete.

NOTE: If the operator presses the STANDBY button together with the START button, the Lock will continue to be roughed to the trip point pressure but will proceed no further with the load cycle. To disengage STANDBY, depress the LOAD button together with the START button and the load sequence will proceed to completion.

4.4.2.4 Automatic Unload Sequence

The unload operation typically follows a load operation and, therefore, the Lock chamber is under vacuum with the roughing valve and interchamber valve door both closed. The unload sequence consists of the following steps.

1. Press the UNLOAD button together with the START button. If the Lock pressure has risen higher than the trip point pressure, the roughing valve will open and the Lock pressure be reduced to the trip point.
2. The unload sequence is automatically executed including venting the Lock to atmospheric pressure.
3. When the LOCK AT ATM indicator illuminates, the Lock door can be opened by depressing both door-actuating switches. The vent valve will automatically close and the elevator will rise to its upper limit.

NOTE: If the operator presses the STANDBY button together with the START button after the unload sequence has been activated, the unload sequence will proceed except that the Lock chamber will not be vented to atmospheric pressure. The processed substrates will be stored under vacuum.

4.4.3 Automatic Pumpdown Controller

The Automatic Pumpdown Controller (APC), with manual override, automatically controls pumpdown and the venting of the sputtering chamber. A schematic diagram display panel (see Figure 4.4-2), provides a dynamic display of system operation. Indicators (LED) provide the operator with visual information of the status of various system elements during processing.

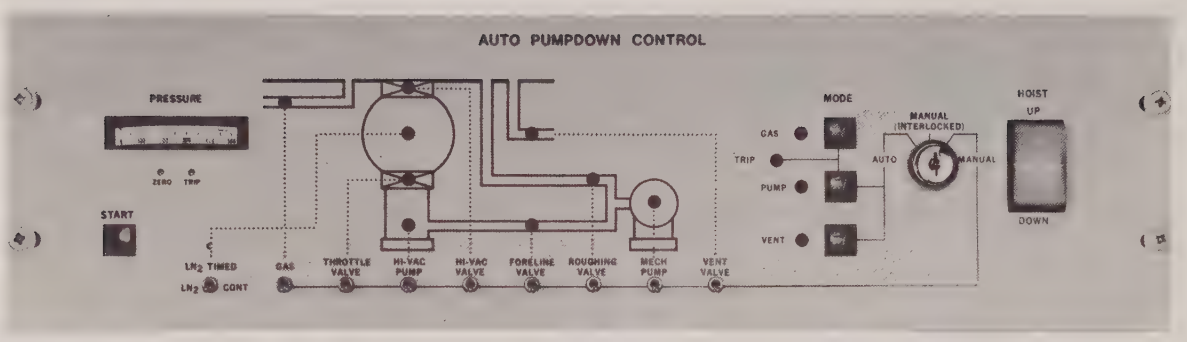


FIGURE 4.4-2 AUTOMATIC PUMPDOWN CONTROLS

The APC is a pushbutton operated unit which provides either a manual or automatic pumpdown of the vacuum system. The controller has three modes of operation: (1) MANUAL (Service mode only), (2) INTERLOCKED MANUAL, and (3) AUTO.

4.4.3.1 Manual Mode Operation

WARNING

DO NOT USE THE MANUAL MODE DURING NORMAL OPERATION. ALWAYS KEEP THE REAR PANEL SWITCH IN "NORMAL OPERATION" POSITION. DO NOT TURN KEY TO THE MANUAL POSITION UNLESS ALL FUNCTION SWITCHES ARE IN PROPER POSITION. IMPROPER OPERATOR ACTUATION CAN CAUSE POTENTIAL DAMAGE TO SUBSTRATES OR THE SYSTEM.

The MANUAL MODE is used for maintenance and servicing purposes only. In this mode, the front panel Key switch is turned to the manual position, all function toggle switches turned OFF, and the rear panel toggle switch positioned into INTERLOCK DEFEAT. The manual mode allows the valves to be driven directly without any interlocking.

4.4.3.2 Manual Interlocked Mode Operation

When the Key switch is placed in the MANUAL/INTERLOCKED position, this mode is used for manual system operation. Although valves are driven by switches, they work only if the switches are actuated in the correct sequence and if the Load Lock is at the correct pressure. The manual/interlock position, like the automatic positions, is fail-safe in that no switch controlled function can be actuated out of sequence.

4.4.3.3 Auto Mode Operation

System operation will become fully automatic with interlock signals, pressure trip points, and time delays, when the key switch is placed in the AUTO position. The AUTO mode consists of four possible conditions:

1. VENT—During this condition, both the high vacuum and the roughing valves close and the vent valve opens. The GAS pushbutton can be used to interrupt venting.
2. PUMP—When this condition occurs, the foreline (if system is equipped with turbomolecular pump) and vent valves close and, if the hoist is down, the roughing valve opens. The chamber is pumped down to a preset crossover pressure (TRIP), at which point the roughing valve closes, then the high vacuum valve opens. The controller then goes into the standby condition. GAS

pushbutton can be used to interrupt pumping. During Standby condition, the roughing valve closes, and the foreline and high vacuum valves open if chamber pressure is below the TRIP point. Chamber pressure is shown on thermocouple gauge meter and the crossover pressure (TRIP) can be adjusted from 10 to 500 microns with 200 microns as the recommended pressure. (The TRIP point on the APC unit must always be on a higher pressure than the TRIP on the Lock Controller.)

3. GAS—In this condition, the high vacuum valve opens, the throttle valve (if so equipped) closes, and the gas solenoid valve opens. PUMP pushbutton shuts off the gas.
4. LOAD LOCK ROUGHING—By definition, every 4400 Series System has a Load Lock. Since the system has only one mechanical pump, foreline for turbomolecular pumped systems, and chamber roughing valves are closed during pump down of the load lock. The high vacuum valve stays open. The gas is shut off during load lock pumping.

To activate any mode, pushbuttons are used simultaneously with the START button.

4.4.4 Gauge Controls

The Model 4410 System is equipped with either a Digital Gauge Control II (DGC) or a Wide Range Gauge (WRG) Control unit that monitors the sputtering pressure and chamber high vacuum pressure (see Figure 4.4-3). Both the DGC and WRG function similarly by providing chamber pressure and by displaying the measurements on the front panels. The operator is responsible for the monitoring and ensuring that the parameters set by the Process Engineer are maintained during the processing.

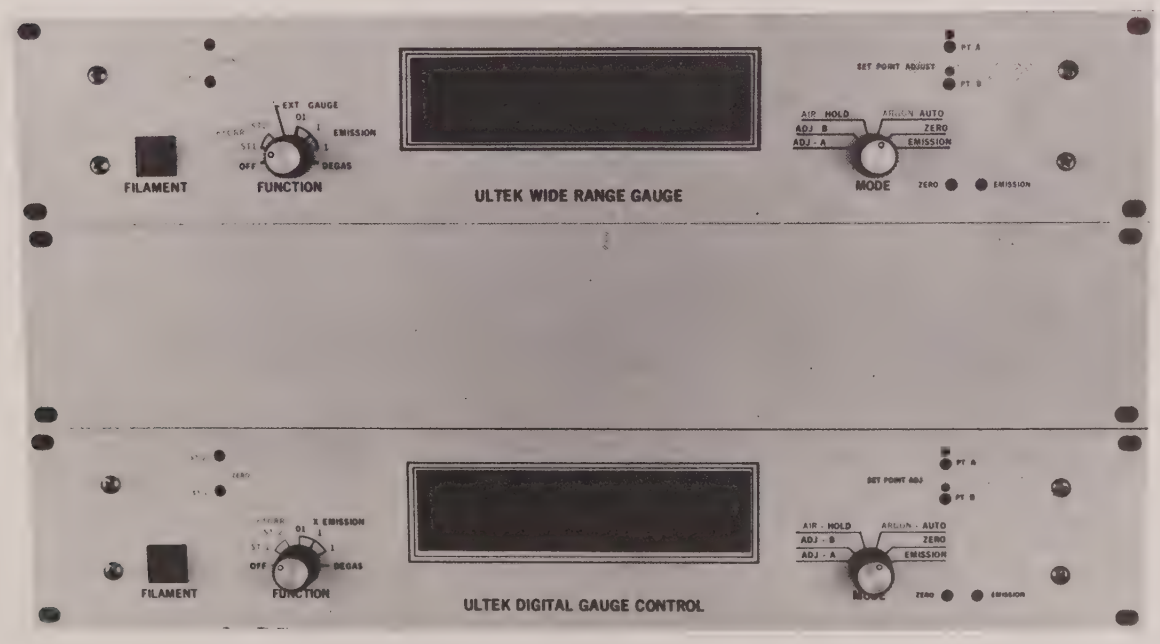


FIGURE 4.4-3 DIGITAL AND WIDE RANGE GAUGE CONTROLS

A number of controls and indicators are provided on the front panel. The functional description of the unit is presented in Table 4.4-2 and the vital operating instructions will be provided by the Process Engineer.

4.4.5 Servo-Match Control

Power from the RF generator is impedance matched to the targets and plasma by means of an impedance matching network built into the sputtering head assembly. This network adjusts the real component of the impedance with an air core transformer in which the primary-to-secondary coupling is varied by moving the primary coil in or out of a coaxial relationship to the secondary coil. This air core transformer, referred to as the load link, is water-cooled and provides DC isolation between the matching network and the generator. The imaginary component of the impedance is adjusted by the variable tuning capacitor.

The Servo-Match continuously and automatically monitors the phase relation between current and voltage in the transmission line and adjusts the sputtering module impedance to provide optimum tuning. It holds the system in tune even if the sputtering mode (sputter deposit, bias sputter, or sputter etch) is changed or if target materials, power level, or cathode-to-anode spacing are varied. Slight adjustment of the load position is sometimes required when the bias level is changed in the bias sputter mode. The Servo Match, as shown in Figure 4.4-4, is operated in either manual or automatic mode.

FIGURE 4.4-4 4410 SERVO-MATCH CONTROL

In the manual mode of operation of the process module matching impedance can be changed by means of TUNE and LOAD switches located on the sputterhead or meter control chassis.

In the automatic mode of operation, the sputterhead network will match RF generator output automatically.

During the automatic mode, the operator can adjust the tuning capability of this unit. The circuit can be tuned for the minimum REFLECTED POWER by inserting a small screwdriver into the appropriate potentiometer hole and slowly turning the screw right or left. This is monitored on the REFLECTED POWER meter on the front panel.

4.4.6 Cryopump Regeneration Control

The cryopump in the Model 4410 System is equipped with a controller which automatically regenerates the pump during an off-shift period (see Figure 4.4-5). After operating for some length of time, as determined by the process engineer, cryopumps must be regenerated to remove the gas molecules that have been adsorbed. The required frequency of regeneration depends on how long the cryopump is used and on the types of gas molecules that are pumped in the vacuum system. In typical production environments, it is recommended that the cryopump be regenerated at least once a week.

Regeneration of the cryopump is initiated by pressing the CYCLE START button on the left side of the control unit's front panel.

Because the process is automatically controlled, the cryopump may be regenerated during an off-shift period. For example, after the last deposition run of the day, the regeneration cycle can be started. The

cycle is then automatically completed and the pump and system are fully functional at the beginning of the next shift. The regeneration cycle lasts 3½ hours and consists of the following steps.

1. The high vacuum valve is closed and the compressor is turned off.
2. A solenoid valve is opened to flood the cryopump with dry gas. Nitrogen or argon gas is recommended. The gas warms the pump and flushes adsorbed gases out of the pump through a pressure relief valve.
3. After approximately 60 minutes, the gas solenoid valve closes and an air-driven roughing valve opens, connecting the cryopump to the mechanical pump roughing manifold.
4. The cryopump is roughed for 30 minutes which reduces the pressure to 20 to 25 microns and assures that water vapor has been removed from the pump.
5. After roughing for 30 minutes, the roughing valve is closed and the compressor restarted.
6. After approximately 2 hours, the cryopump is completely chilled and control is returned to the Automatic Pumpdown Control. If chamber pressure is lower than trip pressure, the high vacuum valve opens.

If chamber pressure has leaked beyond the crossover pressure, the control will prevent the high vacuum valve from opening. With a cryopumped system, the crossover point from roughing to high vacuum may be set as high as 200 to 500 microns. It would indicate a major leak problem or an unclean system if the chamber pressure were to rise above 500 microns in only 3½ hours.

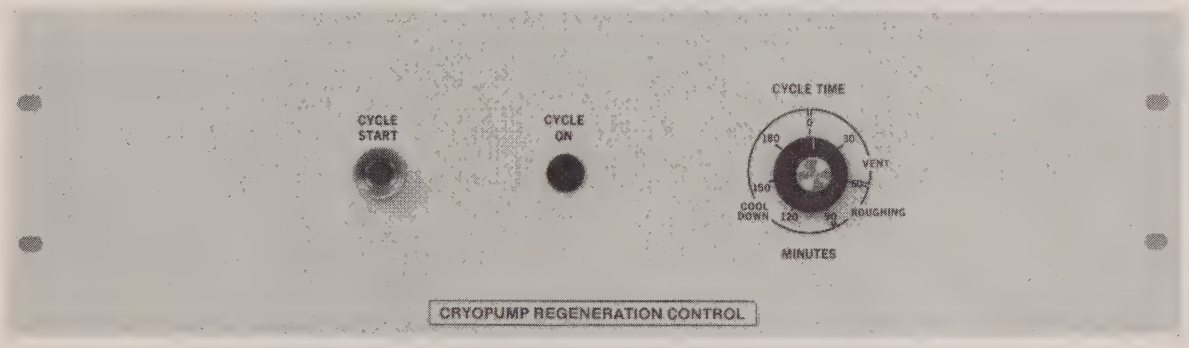


FIGURE 4.4-5 CRYOPUMP REGENERATION CONTROL

4.4.7 Plumbing Purge Control

Another standard item found on all 4410 Systems is the Plumbing Purge Control (see Figure 4.4-6). This feature allows a technician to blow out all the water lines and LN_2 Trap (Meissner) independently. Once the cooling water and LN_2 have been turned off, the Purge Control can be used. By turning either the water or LN_2 purge on, dry nitrogen gas is blown through the lines. This becomes a valuable tool when there is reason to change a target and/or open the vacuum chamber.

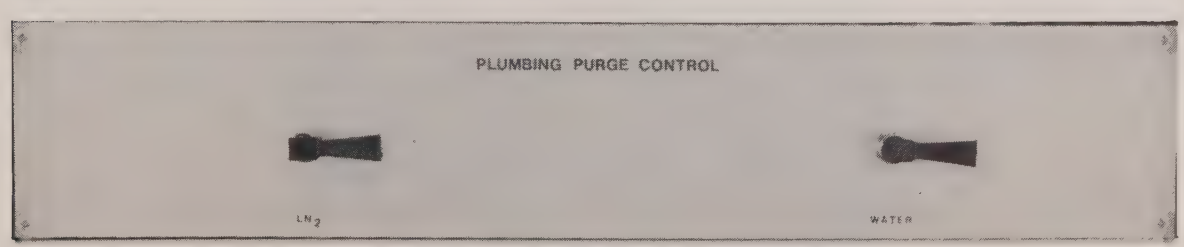


FIGURE 4.4-6 PLUMBING PURGE CONTROL

4.4.8 Power Supply

The Model 4410 System is provided with separate RF or DC power supplies.

4.4.8.1 RF Power Generator

CAUTION

THE OPERATING VOLTAGES INSIDE THE RF GENERATOR ARE LETHAL. DO NOT OPERATE THE GENERATOR WITH ANY OF ITS DOORS OR PANELS REMOVED UNLESS YOU OBSERVE THE UTMOST CAUTION!

The RF power generator consists of a crystal-controlled exciter section, a one-stage linear power amplifier, and a power supply capable of delivering all necessary operating voltages (see Figure 4.4-7). The generator delivers its rated output for continuous-duty operation.

FIGURE 4.4-7 RF GENERATOR

The power tube develops high temperatures during operation, so the generator should be situated where it can be properly cooled. The equipment should be placed far enough away from any wall, furniture, or surface to allow an adequate flow of cool air through the rear vent. Avoid placing any objects on the ventilating grill on top of the generator.

Never operate the generator without connecting the RF output to the sputterhead or a dummy load. All covers and doors must be securely in place for safe operation. Do not defeat the interlocks because they ensure your safety. Always allow about 5 minutes of operation with the RF off before turning the generator off. This allows the power tube to cool and prolongs tube life. The following steps describe the operating instructions of the RF generator.

IMPORTANT

PRIOR TO APPLYING POWER, TURN THE POWER ADJUST CONTROL ON THE CONTROL PANEL OF THE SPUTTERING MODULE FULLY COUNTER-CLOCKWISE (MINIMUM POWER SETTING). MAKE SURE THE UNIT IS UNDER VACUUM.

1. Turn on generator circuit breaker (located on front door).
2. Wait 90 seconds for the tubes to warm up.
3. Push RF ON button once, which is located on sputter module front panel. If the button does not light up, push it a second time.

4.4.8.2 DC Magnetron Power Supply (5 and 10 kW)

The DC Magnetron power supply, as shown in Figure 4.4-8, regulates its output power to a constant Volt-Ampere (VA) product as programmed into the unit by either the manually operated control potentiometer located on the front panel or by use of the BNC connector located on the control box rear panel, J1. The toggle switch on the rear panel, labeled ELEVATE for one position and GROUND in the other position, must be placed into the ELEVATE position when the delta target is to be used. The GROUND position of the toggle switch is for service testing or using the supply for round DC Magnetron targets. Never use this switch while power supply is operating. The digital voltmeter on the front panel indicates target bias voltage.

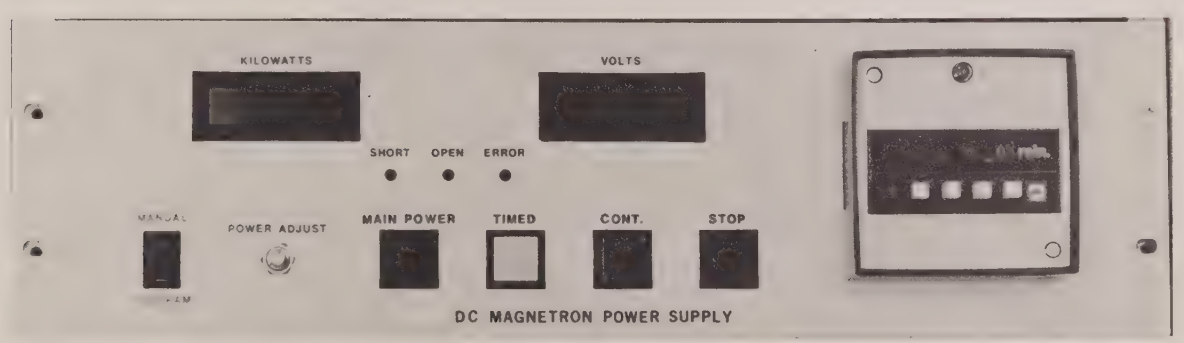


FIGURE 4.4-8 DC MAGNETRON POWER SUPPLY

NOTE

THE "GROUNDING STUD" (ON THE REAR PANEL) MUST BE CONNECTED TO THE SYSTEM SPUTTER HEAD WITH LARGE WIRE (LOW RESISTANCE) AS SHORT IN LENGTH AS POSSIBLE. OUTPUT CURRENTS TO THE SPUTTER HEAD FLOW THROUGH THE GROUNDING WIRE (STRAP) AS WELL AS THE OTHER TWO OUTPUT CABLES.

Three light-emitting diodes are located in the front panel control for reading out the conditions appearing at the output terminals of the supply. They are the following:

SHORT (short circuit appearing across the output)
OPEN (open circuit appearing at the output)
ERROR (appearing anytime the output VA product does not/or cannot match the programmed level, either for manual or programmed inputs).

The error detector measures the differential error between the VA product appearing into the plasma load and the linear input DC voltage used for providing the input programming DC level.

The error indicator may light briefly during the changing of programming levels. It will in fact light anytime the supply begins to approach current limit and/or voltage limit. These two conditions would occur when plasma-impedance changes to either too low or too high a value. It will also light when an arcing condition occurs within the chamber.

To operate the DC Magnetron power supply, the following procedure should be followed (after the system is set-up and ready).

1. Turn power adjust potentiometer fully counter-clockwise to zero power.
2. Turn main power circuit breaker ON.
3. Program/manual rocker switch to MANUAL.
4. Select a predetermined deposition time on timer.
5. Press the CONTINUOUS button to turn DC power on and slowly turn POWER ADJUST knob clockwise to desired power level. The power is read in kilowatts on the digital meter.
6. Open the shutter to the target position that is being used. SHUTTER POSITION switch is located on the front panel sputtering module.
7. As soon as the shutter is activated, press the TIME button. This will then activate the deposition timer and when it times out the DC power will be shut off automatically.
8. After the deposition is completed, always turn the POWER ADJUST knob counter-clockwise back to zero power.

Should a problem arise during deposition, the STOP button should be pushed to turn the DC power off.

4.5 OPERATION

Routine operation of the Model 4410 System is semi-automatic. However, various controls and switches allow the operator to run certain procedures automatically and others manually. These modes of operation are described below.

4.5.1 Process Chamber Control Panel

The control units and indicators are located on the front panel of the processing chamber and head assembly (see Figure 4.5-1). Table 4.5-1 describes the controls and their functions.

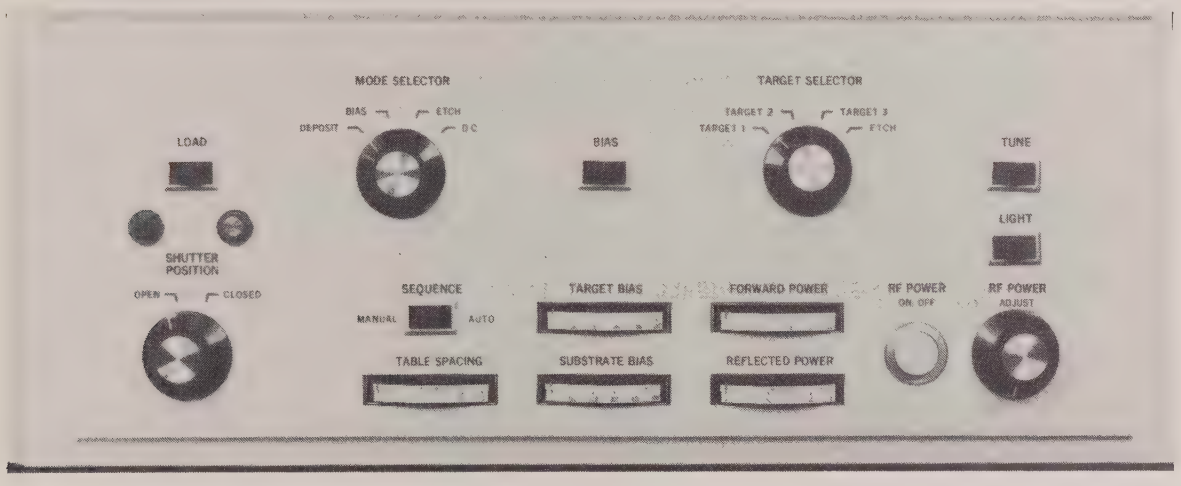


FIGURE 4.5-1 MODEL 4410 SYSTEM PROCESS CHAMBER CONTROL PANEL

4.5.2 Operating Modes

After loading in a pallet of substrates and lowering the Load Lock cover (depressing the two switches just above the Lock Control panel), the operator initiates the cycle by placing the APC and the Lock control into Auto and starts the processing when START and LOAD buttons on the Load Lock controller are depressed simultaneously. The system does the following:

1. Rough Pump – A mechanical pump evacuates the Load Lock to 100 to 200 microns pressure. This takes a few minutes.
2. Hi-Vac Pump—A cryopump continues to evacuate the process chamber to lower than 1×10^{-6} Torr. The Meissner Trap is cooled to trap stray gases, and remains refrigerated until the cycle is finished. After the roughing pump evacuates the Load Lock, the lock valve opens and the substrate pallet is automatically transferred into the chamber for processing. The MODE SELECTOR on the control panel is switched into the desired position.
   a. Deposit Mode—In this mode, the shutter is swung away, the pallet of substrates raised into position, and actual deposition of material begins. During this time the pallet is rotated to assure a uniform coating. The deposition process may take several minutes or hours, depending on deposited material, and is controlled by precision timers.
   b. Bias Mode—Basically similar to Deposit Mode; however, some of the RF power is applied to the substrates as well as the target, which provides for a higher quality coating.
   c. Etch Mode—In this mode, the shutter is kept in the closed position, the power connections into the chamber are reversed so that the material is sputtered from the substrates onto the bottom of the shutter. This cycle cleans the substrates and etches them slightly to receive their coating.
   d. DC Deposit—This mode is essentially identical to the Deposit Mode. However, DC instead of RF power is applied from an external DC power supply.
3. Cycle Complete—The RF power is shut off, and the system is unloaded by pressing START and UNLOAD on the Load Lock Controller. However, vacuum is maintained in the chamber.

4.6 RUNNING THE SYSTEM

The Model 4410 System has a number of controls and adjustments which are not used in everyday production operation of the machine, but which must be preset by the Process Engineer before any attempt is made to run it. The following is a general pre-start check list:

1. The key switches on the APC and the load lock controller are turned to AUTO.
2. The Mechanical Pump and Hi-Vac Pump switches on the APC are ON.
3. The Function Switch on the DGC or WGC must be at .01 and the MODE SWITCH at ARGON-AUTO.
4. The Process Engineer must adjust the argon flow beforehand to assure proper argon gas flow. A regulator pressure of 5 psi is recommended as is the use of a 2-stage regulator.
5. RF or DC power on the power supply must have been turned on and properly adjusted for the mode to be run.
6. Cooling water and LN_2 must be circulating, and the etch or deposition timers are preset.
7. MODE SELECTOR on the front panel switched to the desired processing position.
8. Servo-Match set to AUTO.
9. Power stabilizer OFF (if so equipped).

Once these controls have been verified, the machine may be run according to the instructions in this section. At each stage, the panels on the APC and Load Lock Controller will provide a graphic picture of what is happening, allowing the operator to keep close track of the process.

A typical production run will involve certain interaction between operator and system. Below are examples of operational run sequences for an Etch cycle, an RF Target deposition, and a DC Target deposition.

1. Load Pallet.
2. Close Load Lock door (by pressing both rocker switches down until roughing valve opens).
3. Wait until the automatic load sequence has completed and the LOADED light on the Load Lock Control Panel is ON. Then monitor the chamber high vacuum gauge (WRG or DGC) for chamber recovery to the required base pressure.

ETCH CYCLE

4. Turn the MODE SELECTOR switch to ETCH position.
5. Turn TARGET SELECTOR switch to ETCH.
6. Position SHUTTER POSITION switch to CLOSED.
7. Turn gas on by pressing START and GAS buttons on Auto Pumpdown Control simultaneously. Table starts rotating when gas is on.
8. Allow pressure to stabilize (monitor on vacuum gauge control). If gas pressure needs to be adjusted or changed, use the micrometering valve (located on right side of the sputtering module front panel).
9. Turn RF power on by pressing RF POWER ON/OFF switch. The filament igniter will light in the chamber (it will appear as if a light had turned on in the chamber).
10. Slowly increase the RF power by turning the RF POWER ADJUST knob clockwise. As the RF power is increased both the FORWARD POWER and the REFLECTED POWER meters will indicate the increase. Once RF power has lit a plasma, the following will occur:
    a. The Servo-Match will automatically tune for minimum REFLECTED POWER.
    b. The SUBSTRATE BIAS meter will indicate the substrate voltage level.
    c. The filament igniters will turn off (this is controlled by the bias voltage. A voltage sensor circuit turns igniters off).

11. Increase RF power to required ETCH power for the run.
12. Start ETCH timer (the RF power will be turned off at the end of the timed cycle).
13. After the ETCH cycle has timed out, turn RF POWER ADJUST knob back to minimum (fully counter-clockwise).

RF DEPOSIT CYCLE

14. Turn the MODE SELECTOR switch to DEPOSIT.
15. Turn TARGET SELECTOR switch to Target 2 (for this example, #2 is the RF cathode).
16. Turn RF power on by pressing RF POWER ON/OFF switch. The filament igniters will light in the chamber.
17. Slowly increase the RF power by turning the RF POWER ADJUST knob clockwise. As the RF power is increased both the FORWARD POWER and the REFLECTED POWER meters will indicate the increase. Once the RF power has lit a plasma the following will take place.
    a. The Servo-Match will automatically tune for minimum reflected power.
    b. The TARGET BIAS meter will indicate the target voltage level.
    c. The filament igniters will turn off.
18. Increase RF power to required deposition power for the run.
19. Turn the SHUTTER POSITION switch to OPEN.
20. Immediately start the deposition timer. The RF power will be turned off at the end of the timed cycle.
21. After the deposition timer has timed out, turn RF POWER ADJUST knob back to zero (fully counter-clockwise).

DC DEPOSIT CYCLE

22. Turn the SHUTTER POSITION switch to CLOSED.
23. Switch the TARGET SELECTOR switch to TARGET 1 (in this example TARGET 1 is the DC Magnetron Cathode).
24. Press the CONTINUOUS button on the DC Magnetron Control Panel and slowly turn RF POWER ADJUST knob up (clockwise) to required power level. Power is read on the control panel meters.
25. Turn the SHUTTER POSITION switch to OPEN.
26. Immediately press the TIME button. (The DC power will be turned off at the end of the timed cycle.)
27. After the deposition timer has timed out, turn the POWER ADJUST knob back to zero (fully counter-clockwise).
28. Turn the SHUTTER POSITION switch to CLOSED.
29. On the Auto Pumpdown Controller, press START and PUMP buttons simultaneously. This turns the gas off.
30. Monitor base pressure recovery on the Vacuum Gauge Control, if process requires this.
31. On Load Lock Control panel, press START and UNLOAD buttons simultaneously. The pallet will now be transferred back to the Load Lock chamber automatically and the Lock vented.
32. When the Lock at ATM light comes on (located on the water flow switch panel), push both Load Lock door rocker switches to UP position and hold until the door is opened all the way. The elevator will then raise the pallet automatically.
33. Unload pallet and reload next run.

TABLE 4.4-2

DGC AND WRG CONTROL AND INDICATOR FUNCTIONS

NAME	REFERENCE DESIGNATION	FUNCTION
FUNCTION Switch:	S1	
OFF		De-energized gauge control unit.
ST1		Connects to station 1 thermistor gauge.
ST2		Connects to station 2 thermistor gauge.
EXT. GAUGE*		Enables 10^{-2} Torr scale on the WRG only.
EMISSION		Provides three multiplier emission indications, X.01, X.1, and X1.
DEGAS		75 W of degas power for resistance heating of the grid.
FILAMENT Pushbutton Switch/Indicator	S3	Switch turns gauge tube filament ON and OFF. Indicator lamp is ON when filament is on. Indicator lamp is OFF when filament is off. Switch has pushbutton action.
Five-Digit Display	V1	First display segment (V1) indicates a negative signal by showing a minus sign. This segment will also display a 1, when applicable, during hold modes, emission check, and first digit segments during thermistor gauge operation. This display also indicates second and third segments of pressure or emission in units and tenths, respectively.
	V3	Fourth and fifth display segments indicate exponent of negative powers of ten.
Display Multiplier	V2	Graduated in .10 Torr units and is disabled when switched to functions other than pressure measuring mode.
MODE Switch:	S2	
ADJ-A		Sets Limit-A for set point function.
ADJ-B		Sets Limit-B for set point function.
AIR-HOLD		If FUNCTION switch is in ST1 or ST2 positions, the thermistor gauge will give an air-calibrated pressure indication. If the FUNCTION switch is in one of the emission positions, automatic range switching is disabled and the WRG or DGC will be held in existing operating range.
ARGON-AUTO		If the FUNCTION switch is in ST1 or ST2 positions, the thermistor gauge will given an argon-calibrated pressure indication. If the FUNCTION switch is in one of the emission positions, pressure ranges will switch automatically with the exponent portion of the display indicating the existing range.
EMISSION		Permits the electron emission to be set.

ZERO (Screwdriver Adjustment)	R2	Located at the right end of the front panel, this adjustment is used to calibrate the DGC or WRG electrometer circuitry with the MODE switch in the ZERO position using the display on the DGC or WRG.
ZERO/ST1 ZERO/ST2 (Screwdriver Adjustment)	R4 R11	These adjustments allow the zero pressure calibration of the two thermistor gauges. ST1 ZERO is adjustable with the FUNCTION switch in the ST1 position and ST2 ZERO is adjustable when the FUNCTION switch is in the ST2 position.
EMISSION (Screwdriver Adjustment)	R3	Used to set emission control level with MODE switch in the EMISSION position in both the DGC and WRG.
SET POINT ADJ:		
PT.A		Establishes Set Point-A; illuminates adjacent LED when set point is reached.
PT.B		Establishes Set Point-B; illuminates adjacent LED when set point is reached.

*Only on Wide Range Gauge (WRG).

TABLE 4.5-1

MODEL 4410 PROCESS CHAMBER CONTROL PANEL AND INDICATORS

ITEM	FUNCTION
LOAD CONTROL	Adjusts coupling between primary and secondary circuits of the matching network. Used in conjunction with the TUNE switch and FORWARD AND REFLECTED POWER indicators. The LOAD switch drives a motor which controls the setting for the RF tuning coil. The TUNE switch drives a motor which controls the setting of the RF tuning capacitor. These two switches are used manually to match RF power to the load. They are overridden by the Servo-Match Control when it is operated in the Automatic Tune Mode.
MODE SELECTOR 1. Sputter Deposit	In this mode, all RF power is applied to the target; i.e., only the target is bombarded by ions and sputtered. The substrate table is grounded. Self-bias is read on the TARGET BIAS meter.
2. Bias Sputter	RF power is applied to the target, but a small amount of RF power is also applied to the substrate table. Consequently, substrates also are bombarded by ions but to a much smaller degree than the target. In many cases this technique yields higher quality deposits than RF sputtering with grounded substrates. Bias is read on the substrate BIAS meter.
3. Sputter Etch	All RF power is applied to the substrate table and material is removed (etched away) from the substrates by ion bombardment. Self-bias is read on the SUBSTRATE BIAS meter.

4. DC Bias (Optional)	This mode is essentially the same as sputter deposit. However, instead of grounding the substrates table, a DC bias can be applied to it from an external DC power source.
BIAS ADJUST	Active only in the bias sputter operating mode. This control adjusts percentage of RF power applied to the substrate table. Varying amount of power results in varying negative self-bias on the table. This bias is measured by the SUBSTRATE BIAS meter. This meter measures energy with which ions from the discharge strike the substrate table.
TARGET SELECTOR Target 1, 2, 3, & etch	Connects output of the matching circuit to any of the three targets and substrate table. This switch has four positions. At Target 1, RF power is applied to the left target, as viewed from the front of the unit; Target 2 is the rear target; Target 3 is at the right. At the ETCH position, RF power is applied to the substrate table.
TUNE CONTROL	Adjusts parallel capacitance in the target circuit of the matching network. (Refer to LOAD CONTROL explanation.)
SHUTTER POSITION Switch Open/Closed	This two-position switch actuates a motor which opens and closes a rotatable disk shutter interposed between the substrates and target. In the OPEN position, the shutter opening permits deposition. In the CLOSED position, it permits etching or target cleaning.
TABLE SPACING	Informs the operator the table spacing measurement between the substrate table and the target surface. Scale is from 0 to 5 inches.
SEQUENCE SWITCH Auto/Manual	Used to switch load commands for remote operation. Must be in AUTO for microprocessor operation.
REFLECTED POWER Meter	Measures amount of RF power flowing back from sputtering unit to power supply due to impedance mismatching between the power supply and the load. This reflected wave combines in the cable with the forward wave to form standing waves which, in turn, cause heating of the cable. With proper adjustment of LOAD and TUNE controls, reading on the REFLECTED POWER meter will dip below 25 watts typically for R.F. generators of 3 kW or less. Residual reflected power is due to transitions on the cable (such as connectors, etc.) and cannot be totally eliminated.
RF POWER ON/OFF SWITCH	Actuates, through a special logic circuit, a high-voltage relay in the RF power generator. The on/off function is interlocked by a pressure interlock switch so RF voltage cannot be applied to targets while they are exposed to atmospheric pressure. Applying high RF voltage to exposed targets can result in arching and breakdown around target edges. Target assembly is designed for operation at low pressures where breakdown distance is much longer than at atmospheric pressure.

RF POWER ADJUST CONTROL	Governs power output from the RF power generator. This quantity is displayed on the FORWARD POWER meter.
LIGHT SWITCH	Manual Control of filament igniter to allow observation in the chamber. When depressed, the chamber will be illuminated by the filament.

SERVICE BULLETIN

No. 110
19 March 1980

PERKIN-ELMER

Plasma Products Division

PREVENTIVE MAINTENANCE - 4400 SERIES

This notice is to inform you of Perkin-Elmer's recommended maintenance interval on the 4400 Series Production Sputtering Systems.

WEEKLY

1) Check servo-match operation.
2) Clean all ground shields in chamber as needed.
3) Clean shutter and pallet as needed.
4) Check continuity of ignitor filaments; visually check filaments. If either loop is broken, replace both loops.
5) Check water connections for leaks.
6) Daily zero and calibrate thermocouple and thermistor gauges.
7) Daily zero and calibrate ion gauge.
8) Remove ground rings on targets and clean as needed.
9) Assure that chains and bearings in both lock and sputter chamber drive rail assembles are properly aligned.
10) Check hinge assembly on lock door for safety.
11) Clean and grease O-ring in load lock valve door.
12) Clean and grease load lock door O-ring.
13) Check alignment of pallet/carrier to drive rails assemblies, sputter table, carriage stops, and lock elevator.

MONTHLY

1) Check all interlock operations

THREE MONTHS

1) Examine all finger stock associated with table etch mode.
2) Check pressure levels on the compressor.
3) Change turbo pump oil.

4400

P.O. Box 10920, Palo Alto, CA 94303, Phone:(415)967-2100, TWX:910-379-6442

SERVICE BULLETIN

Bulletin #112
June 25, 1981

PERKIN-ELMER

Plasma Products Division

4400 SERIES

4400 SERIES PRE-INSTALLATION REQUIREMENTS*

The initial installation of a 4400 sputtering system is the joint responsibility of the Customer and Perkin-Elmer Plasma Products Division. The installation site must be prepared by the customer (all utilities such as gases, water, and power must be installed and ready for connection) before the arrival of a Perkin-Elmer Field Service Engineer. Connection of utilities to a system is the Customer's responsibility and should be done in the presence of a Perkin-Elmer Field Service Engineer at the time of installation. Initial system power-turn-on must be conducted by a Perkin-Elmer Service Engineer only. Warranty is valid only if utility installation is inspected and approved, and system start-up supervised by Perkin-Elmer.

A complete instruction manual along with blue prints is shipped to the Customer. Consult documentations for details to prepare the site. (Special NOTE: There are errors on page 2-4 of the 4410 manual regarding power requirements. Do not use the information on page 2-4. Use only the following information when installing facilities.)

REQUIRED FACILITIES

	Process Chamber	Vacuum System	2KW RF Generator	10KW DC Power Supply
Voltage	-	208 Vac(1)	208 Vac	208 Vac(2)
Freq./Phase	-	60 HZ/3 Phase	60 HZ/ Single	60 HZ/3 Phase
Amperage	-	60(10)	(3)	75 AMP.(4)
Water	(5)	(6)	0.5gpm (7)	1.50(12)
Dry N_2	-	10-20 psig(11)	-	-
Argon	5-10 psig	-	-	-
LN_2	-	2L/hr. (9)	-	-
Air	-	60-70 psig(8)	-	-

(1)

*Includes 4400, 4410, 4415, 4450 Sputtering Systems only

11. For venting load lock and process chamber. Full flow regulator is recommended for faster venting.

12. Water flow required for Delta magnetron cathode cooling only in DC operation. Water requirement for the systems using 8" cathode is 1.25 G.P.M.

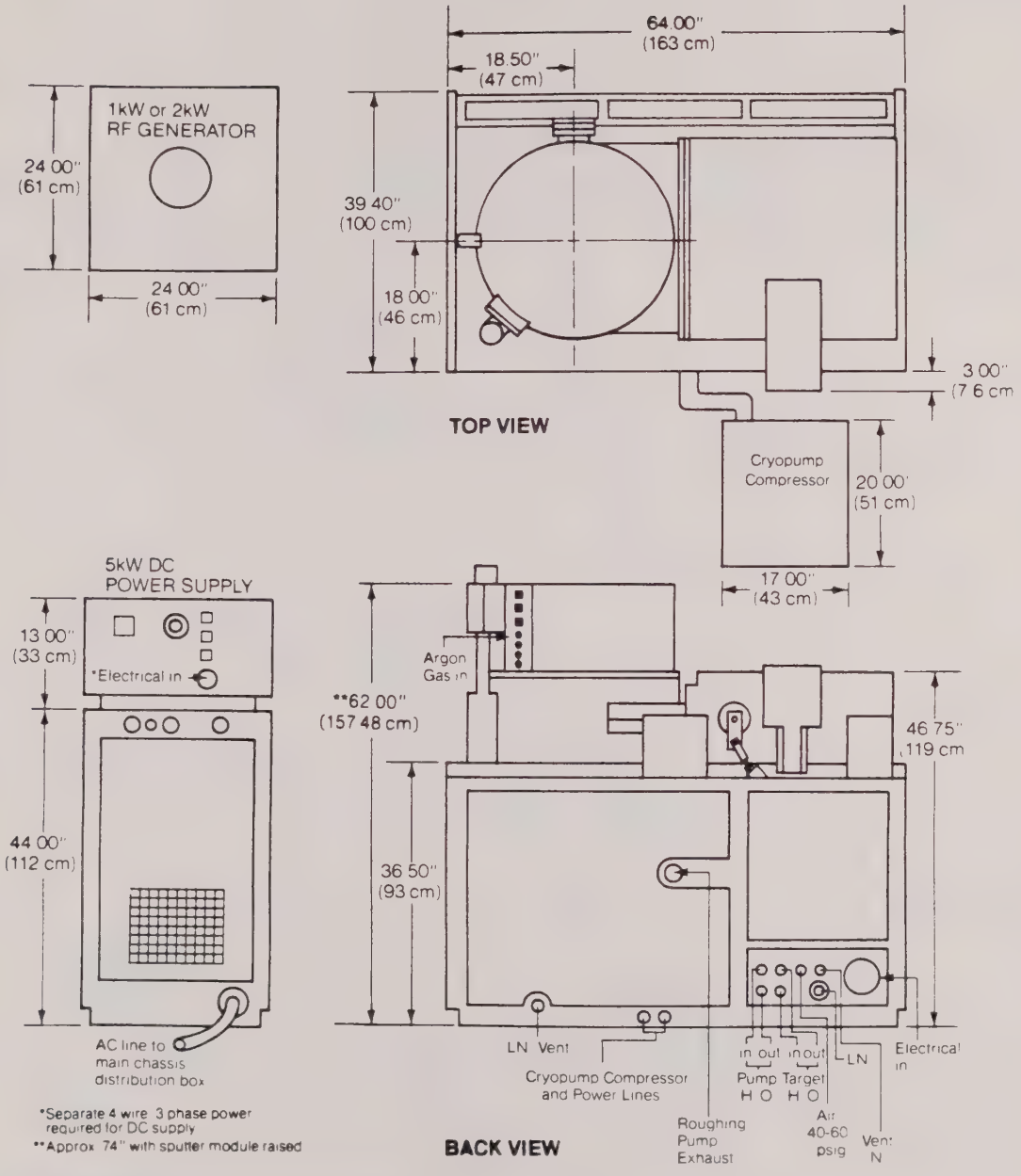
External shut-off valves and fuse disconnect are recommended for all utilities. Dual stage regulators required for compressed gas.

SYSTEM UTILITY CONNECTIONS

	Process Chamber	Vacuum System	RF Generator	DC Power Supply
Power		5 wire 208V 60 A (direct hook-up)		4 wire 208V 75 A 10KW 40 A 5KW (direct hook-up)
Water	1/4" FPT	1/4" FPT	1/4" FPT(7)	1/4" FPT(12)
Dry N_2		1/4" FPT		
Argon	1/4" Swagelok			
Air		1/4" FPT		
LN_2		1/2" OD Tube		

NOTE: All utility connections should be flexible to allow some movement of system when necessary. Complete access of system is required for servicing.

Model 4400 Dimensions



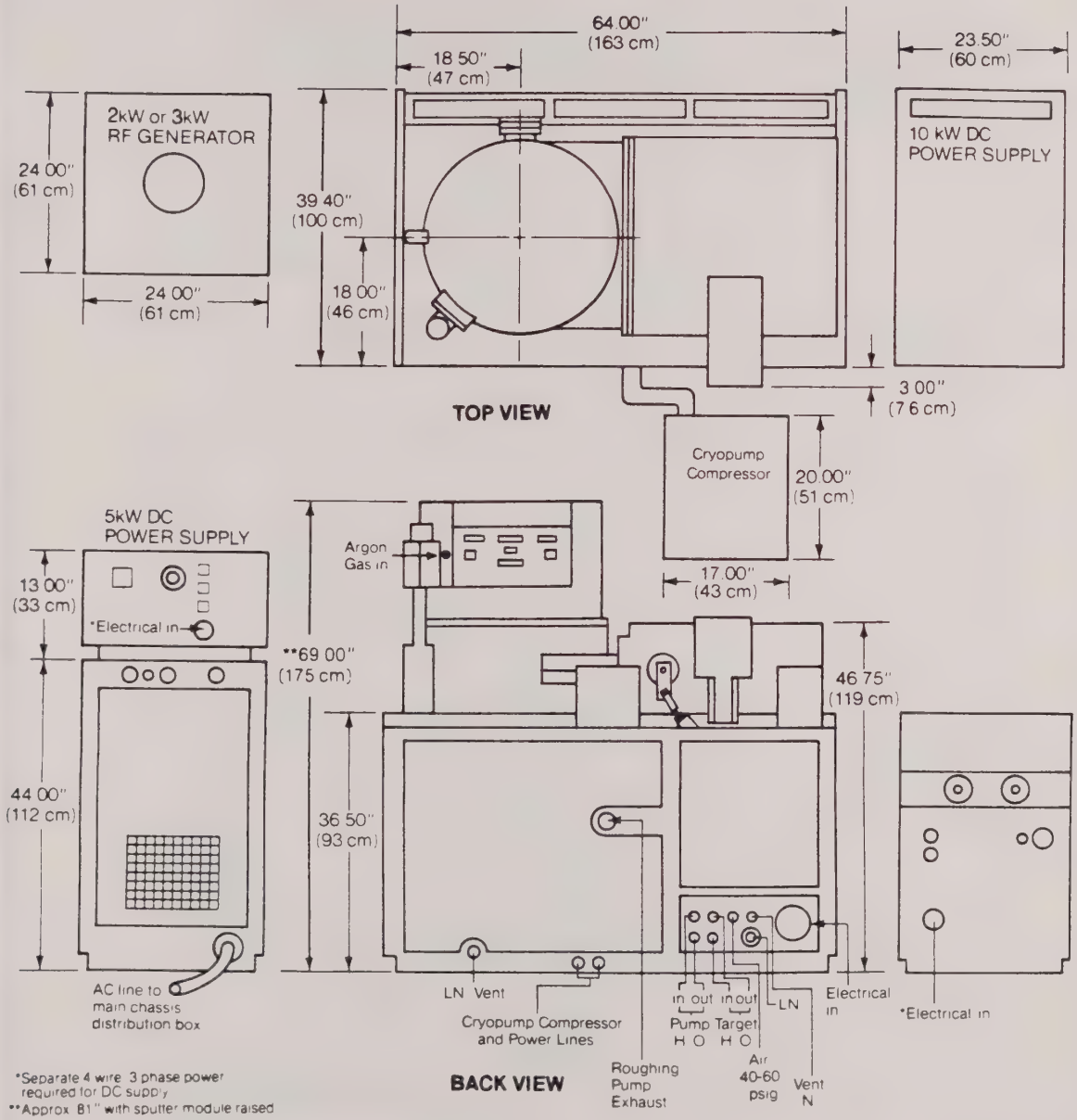
SHIPPING WEIGHT APPROX. 2,500 LBS

PERKIN-ELMER **Plasma Products Division**

P.O. Box 10920, Palo Alto, CA 94303, PHONE: (415) 967-2100, TWX: 910-379-6442

PB 4400 5/79 15M

Model 4410 Dimensions



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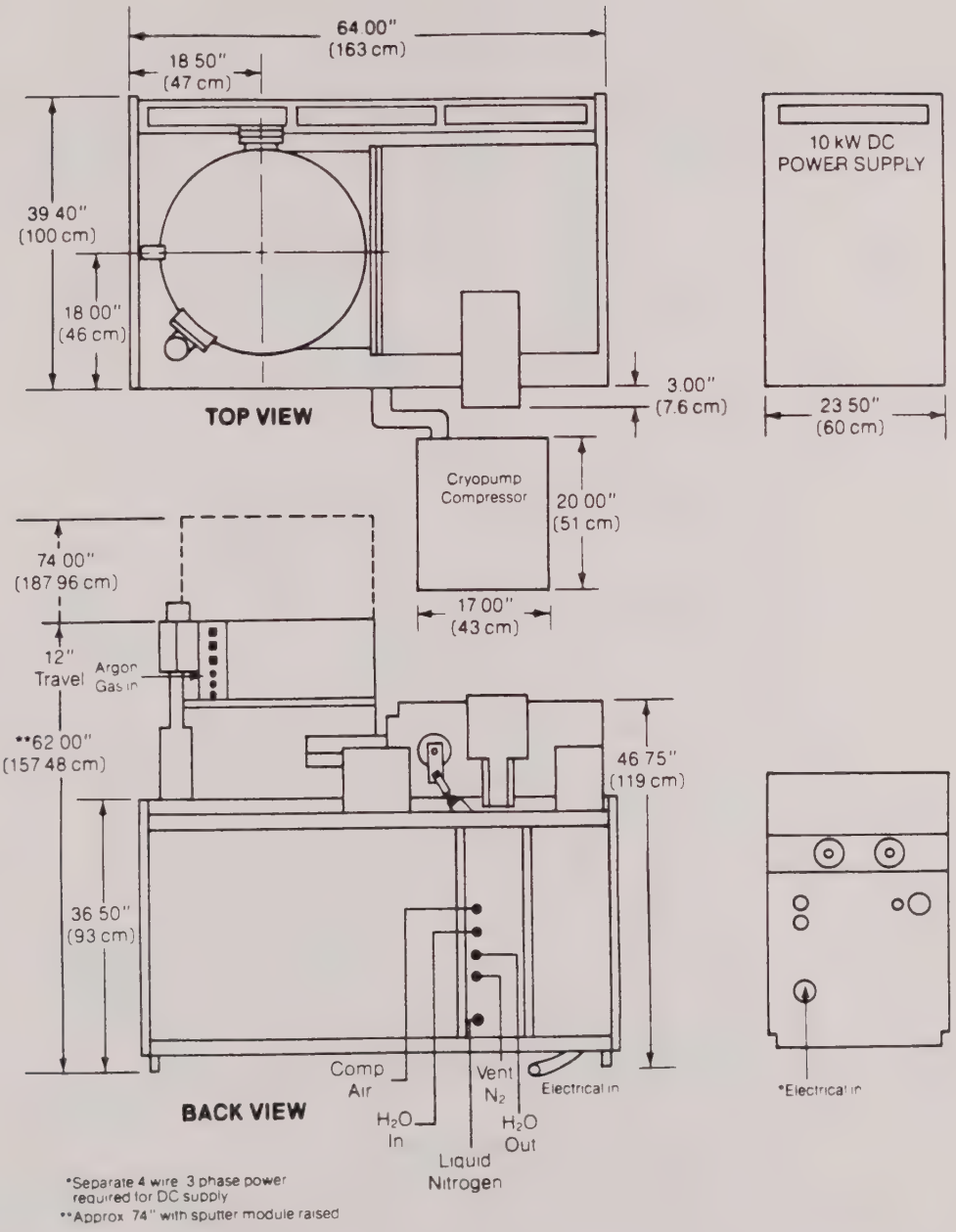
PE 4410 6/79/15M PRINTED IN U.S.

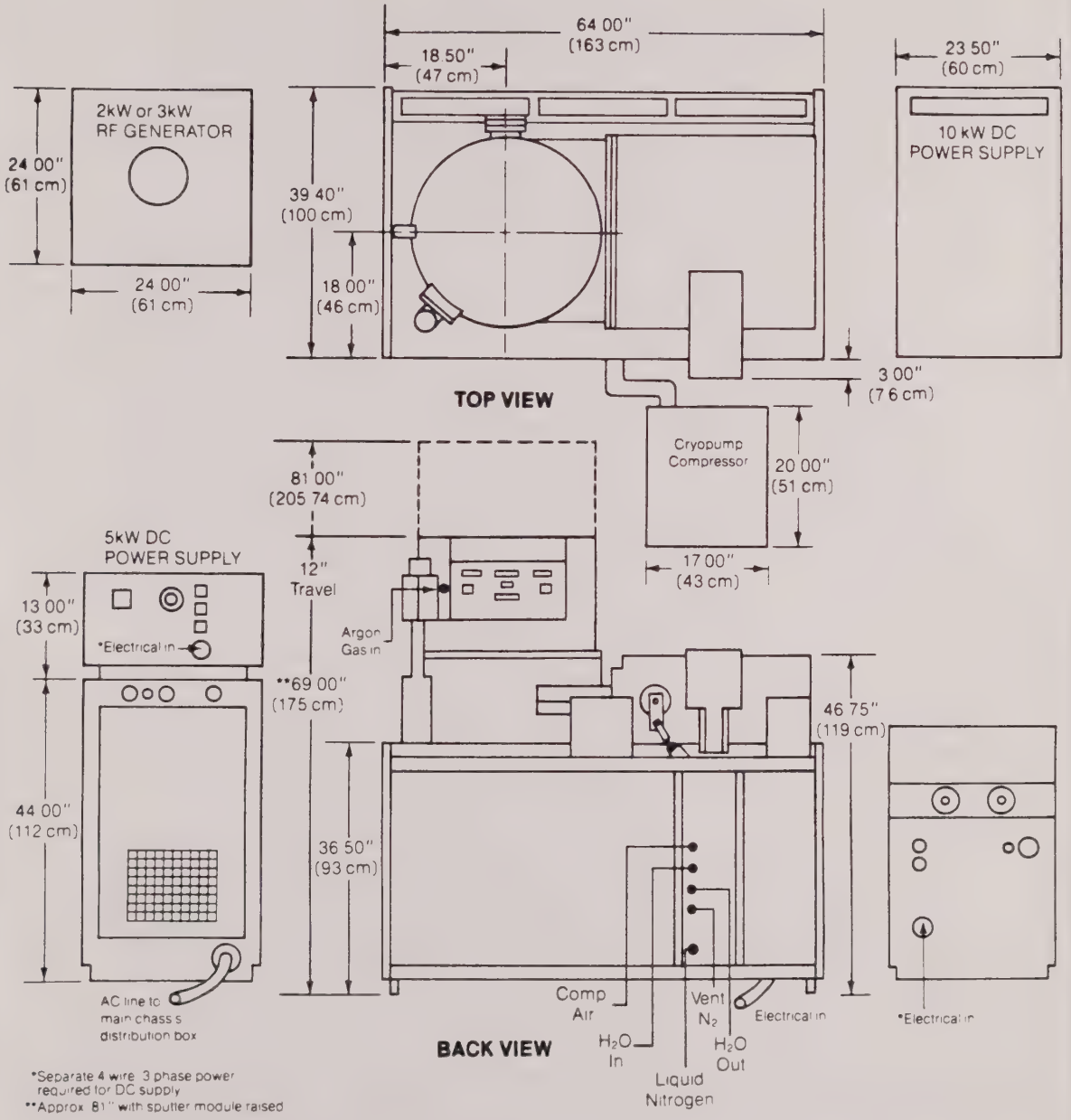
Model 4415 Dimensions



SHIPPING WEIGHT APPROX 2,500 LBS

PERKIN-ELMER Plasma Products Division
P.O. Box 10920, Palo Alto, CA 94303, PHONE: (415) 967-2100, TWX: 910-379-6442

Model 4450 Dimensions



SHIPPING WEIGHT APPROX 3,000 LBS

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APPENDIX A

PROGRAMMABLE POWER STABILIZER

INTRODUCTION

The function of the Programmable Power Stabilizer is identical to the manual stabilizer described in section 3.5.1. Figure A-1 shows the physical location of all the controls and indicators used on the Programmable Power Stabilizer, and their functions are described in table A-1.

The three modes of operation are Manual, Automatic, and Stabilizer off.

Figure A-1 PROGRAMMABLE POWER STABILIZER CONTROLS AND INDICATORS

MANUAL OPERATION (with plasma ignited in the system)

1. Set STABILIZATION switch to ON.
2. Set MODE switch to MAN.
3. Set MANUAL POWER ADJUST potentiometer to desired position. RF power to the sputtering head is now adjustable for any desired operation.

CAUTION

RF POWER SHOULD NOT BE TURNED ON WITH STABILIZATION SWITCH ON. OTHERWISE, DAMAGE MAY RESULT TO THE RF GENERATOR.

AUTOMATIC OPERATION

1. Set the STABILIZATION switch to ON.
2. Set MODE switch to the AUTO position. RF power to the sputtering head is now adjustable by the appropriate AUTO-POWER ADJUST trim-pot, as indicated by panel light indicator.

NOTE: A 5-second power ramping is available, for power levels 1-9, when the RAMP switch is ON. If none of the 10 available trim-pots are selected, RF power will remain at the minimum level.

STABILIZATION OFF MODE

1. Set the STABILIZATION switch to OFF.
2. Set the MODE switch to either AUTO or MAN position. In this mode of operation there is no stabilization of the RF power. The RF power level is manually controllable by the RF POWER ADJUST potentiometer on the system meter panel.

TABLE A-1

CONTROLS AND INDICATORS (PROGRAMMABLE STABILIZER)

NAME	FUNCTION
STABILIZATION-ON/OFF Pushbutton/Indicator Switch	Used for turning on and off the Programmable Power Stabilizer. (In OFF position, RF power is manually controlled.)
RF POWER Meter	Used to indicate the amount of forward RF power being applied to the system.
AUTO-POWER ADJUST Ten potentiometers and ten indicators	Used for adjusting ten precise levels of RF power.
MANUAL POWER ADJUST Ten-turn variable potentiometer	Used during manual operation for applying stabilized power.
MODE-AUTO/MAN Pushbutton/Indicator Switch	Used to select automatic or manual operation. In AUTO, allows selection of any of the ten potentiometers. In MAN selects the MANUAL POWER ADJUST ten-turn potentiometer.

CTI-CRYOGENICS

M8040003

INSTALLATION, OPERATION AND SERVICING INSTRUCTIONS

CRYO-TORR(R) 8 HIGH-VACUUM PUMP*

DECEMBER 1980

*Note

Users of cryogenic equipment that includes the water-cooled Model 350SCW Compressor Unit, rather than the air-cooled Model 350SC Compressor Unit should consult the Addendum at the rear of this manual before installing and operating that equipment.

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HELIX

Kelvin Park Waltham, Massachusetts 02254 (617) 890-9400 Telex 92-3442

RETURN OF EQUIPMENT

If it is necessary to return equipment to CTI-CRYOGENICS, contact the Product Service Department for instructions. More specifically, contact:

CTI-CRYOGENICS
Product Service Department
Kelvin Park, 266 Second Avenue
Waltham, Massachusetts 02154, U.S.A.
Telephone (617) 890-9400
Telex 92-3442
Cable Address - CRYOTI

The following information for each item being returned will aid in assuring prompt response:

Equipment Name
Serial Number
Part Number
Date of Purchase (if possible)
Sales Order No. of CTI-CRYOGENICS (if possible)

You will be given an RGA (Returned Goods Authorization) number. This number is necessary for all returned equipment. It must be clearly indicated on both the shipping carton(s) and any correspondence relating to the shipment.

Note: The User should retain the shipping carton(s) in which equipment is originally received from CTI-CRYOGENICS, for convenience in case any equipment has to be returned to CTI-CRYOGENICS.

WARNING: IF THE CRYOPUMP HAS BEEN USED TO PUMP TOXIC OR HAZARDOUS MATERIALS, IDENTIFY THIS FACT CLEARLY WHEN SHIPPING UNIT TO CTI-CRYOGENICS.

TECHNICAL INQUIRIES

Technical inquiries that the User may have concerning the installation, operation, or maintenance requirements of his equipment should be directed to the Product Service Department of CTI-CRYOGENICS. (See contact information above.)

TABLE OF CONTENTS (continued)

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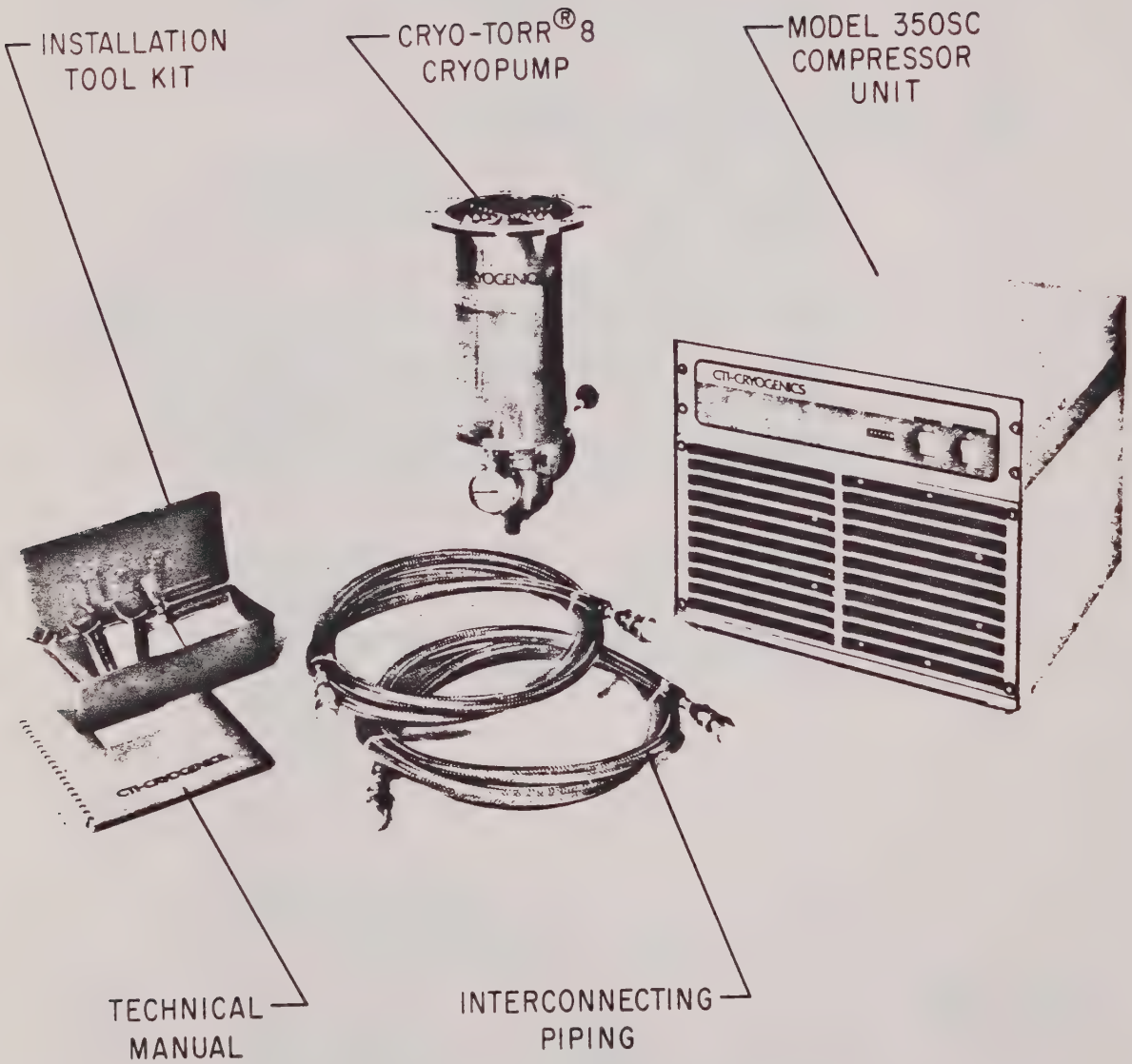


FIGURE 1-1. THE CRYO-TORR® 8 HIGH-VACUUM PUMP

CHAPTER 1
INTRODUCTION

1.1 GENERAL

The CRYO-TORR(R) 8 High-Vacuum Pump provides fast, clean pumping of all gases in high-vacuum applications. This high-vacuum pump (see Figure 1-1) consists of the CRYO-TORR 8 Cryopump, the Model 350SC Compressor Unit, interconnecting piping, and an installation tool kit.

The high-vacuum pump, which uses helium as the refrigerant, is designed to interface with many kinds of apparatus used in high-vacuum technology, including ion implanters, particle accelerators, sputtering systems, and deposition systems. Along with a pumping speed of 1,500 liters per second for air, this pump also offers high reliability and cleanliness for operation in a wide variety of applications in science and industry.

1.2 DESCRIPTION OF COMPONENTS

1.2.1 CRYOTORR 8 Cryopump (see Figure 1-2 and also Figure A-1 of Appendix A)

The CRYO-TORR 8 Cryopump, which is identified throughout this manual as the cryopump, consists principally of the cold head (19, Figure 1-2), a vacuum housing (17), and two condensing arrays (1, 2), a cryo-adsorbing array (3), and a radiation shield (4) that are installed in the vacuum housing. The cold head (see Figure 1-3) is rigidly attached to the vacuum housing and is used to cool the three arrays.

The cold head is connected by interconnecting piping (see Figure 1-1) to a remote helium-gas compressor unit (see Figure 1-4). The power switch (2, Figure 1-4) that controls the cold head (and hence the cryopump) is located on the compressor unit.

The condensing and cryo-adsorbing arrays are attached to the cold-head cylinder (5, Figure 1-2) with screws to facilitate easy removal. Gases present in the User's vacuum system are removed by either cryo-condensing or cryo-adsorbing them upon these arrays.

1.2.1.1 Vacuum Housing and Associated Arrays (see Figures 1-2 and A-1)

The 80K condensing array (1, Figure 1-2) freezes out water and hydrocarbon vapors. The 15K condensing array (2) cryo-condenses nitrogen, oxygen, and argon. In addition, helium, hydrogen, and neon are cryo-adsorbed on the charcoal of the 15K cryo-adsorbing array (3). The temperature of the cold station (9) to which the two 15K arrays are attached is measured by means of a hydrogen-vapor-pressure gauge (14). (The CRYO-TORR(TM) Vacuum-Pump Temperature Indicator is available as an optional accessory to read that temperature when the cryopump is equipped with the optional silicon-diode temperature sensor.)

The 6-inch ANSI mounting flange (13) of the vacuum housing (17) contains an O-ring groove that accomodates a #2-172 Viton O-ring. (The CRYO-TORR 8 Cryopump is also available with a 10-inch-OD metallic-seal mounting flange.) This flange is the interface with the User's vacuum system.

Note: If the mating flange of the User's vacuum system also has an O-ring groove, it may be necessary to interpose a double-sided, flat-faced spacer ring between the two flanges.

The vacuum housing contains an accessory port (29), which can be modified so that a roughing valve and/or a vacuum gauge can be connected to it. The accessory-port cover (30) is sealed to the vacuum housing by an O-ring, and can be modified to accept a 3/4-inch (maximum) OD tube. The accessory port, when fitted with a roughing valve, can be used for re-evacuating the vacuum housing after regeneration (see Chapter 4).

WARNING: DO NOT INSTALL A HOT-FILAMENT GAUGE (ION GAUGE) ON THE CRYOPUMP SIDE OF THE HI-VAC VALVE (SEE SECTION 2.4). IT COULD BE A SOURCE OF IGNITION FOR FLAMMABLE GASES.

The vacuum housing also contains a relief valve assembly (18), which will open at 2 to 3 psig to prevent overpressure that might develop during regeneration as the condensed gases vaporize.

1.2.1.2 Cold Head (see Figures 1-2 and 1-3)

The function of the cold head (19, Figure 1-2) is to produce continuous closed-cycle refrigeration at temperatures that, depending upon the heat load imposed, are in the range of 77K to 100K for the first-stage cold station (7) and in the range of 12K to 20K for the second-stage cold station (9).

Note: Refer to Appendix E for an explanation of the principles of operation by which the cold head and compressor unit employed in the CRYO-TORR 8 High-Vacuum Pump achieve cryogenic levels of refrigeration.

The cold head has three major components: the drive unit (23), the cylinder (5), and the displacer-regenerator assembly (28), which is located inside the cylinder.

The drive unit consists of the following subassemblies: the drive motor (24), the crankcase (26), and the drive mechanism (25), which is located inside the crankcase. The drive mechanism is attached to the drive-motor shaft. As this shaft rotates, the drive mechanism imparts reciprocating motion to the displacer-regenerator assembly, while at the same time operating the inlet and exhaust valves. This controls the flow of helium gas through the cold head.

The drive motor is a direct-drive, constant-speed motor that operates at 72 rpm on 60-Hz power and at 60 rpm on 50-Hz power. It is enclosed within a sealed housing and is attached to the crankcase. The motor housing has two connectors: one is the electrical power connector (22), through which power is supplied; the other is the helium-gas return connector (21).

The incoming high-pressure helium gas from the compressor unit enters the crankcase through the helium-gas supply connector (20). The gas then passes through the inlet valve and into the displacer-regenerator assembly. The return (exhaust) flow passes from the displacer-regenerator assembly, out through the exhaust valve and into the crankcase, through the motor housing, and thence through the helium-gas return connector (21) to the compressor unit. The expansion of helium gas through the displacer-regenerator assembly provides cooling at two discrete temperatures (at the first- and second-stage cold stations).

1.2.2 Compressor Unit (see Figure 1-4)

The compressor unit consists of the following major components: a hermetic compressor pump, a cooling system, an oil-injection system, an oil separation system, and an adsorber. In addition, the compressor unit contains instrumentation, controls, and protective devices.

The compressor unit also houses the electrical-control-chassis components required to operate the compressor unit and the cryopump. (The electrical-control panel and chassis located at the front of the compressor unit can be removed and mounted at a separate location; see Section 2.6). A grounded input power cable (4, Figure 1-4) and a cold-head power cable (5) are provided as integral parts of the compressor unit.

> Note: Refer to Appendix B for information relating to the electrical circuits of the compressor unit.

The compressor unit is designed for unattended operation. A helium-supply pressure gauge (7), an elapsed-time meter (3), and two power switches (1, 2) provide all of the needed instrumentation. Functional descriptions of the controls, indicators, and other features of the compressor unit are given in Table 1-1.

1.2.2.1 Gas and Oil Flows in the Compressor Unit (see Figure 1-5)

The low-pressure return-flow helium from the cold head in the cryopump enters the compressor unit through the gas-return connector (8, Figure 1-4). After passing through a check valve, the helium goes to the compressor pump. The check valve prevents any of the particulate oil that has been injected into the helium return line to the compressor pump for cooling purposes from backstreaming into the cold head.

The helium-and-oil mixture passes through the rotary-vane compression device depicted in Figure 1-5 and exits as the "1st discharge from the pump." The rotary vane is mounted (with a slip fit) on a vertical shaft that is driven by an electric motor located directly below the vane. As the shaft rotates, the vane (a) rotates within a cylinder that is located eccentrically with respect to the shaft and (b) slides back and forth with respect to the shaft. The return-flow helium enters the bottom of the off-center cylinder and after being compressed by means of the arrangement described discharges from the cylinder through a reed-type valve located in the top of the rotary vane compression device.

The hot oil-and-helium mixture discharged from the rotary-vane compression device passes through the No. 1 gas-to-air heat exchanger, where it is cooled by the fan assembly. As the mixture cools, much of the oil in it condenses. The high-pressure mixture passes through the compressor-pump housing where the oil drops separate from the helium. Oil drops into the sump of the pump and the helium removes heat from the electric drive motor. The gas stream then passes through the No. 2 gas-to-air heat exchanger where the cooling reduces the helium temperature and condenses the remaining oil particles. This particulate oil is removed from the helium by the oil separator. The 350-psig system relief valve in the oil separator assembly

protects against overpressure. The separated oil is returned to the compressor pump after passing through a filter and an orifice. The orifice minimizes the bypassing of helium along with the separated oil. The filter prevents the orifice from becoming clogged with any foreign matter.

As it leaves the oil separator, the helium gas stream is free of particulate oil but does contain a minute quantity of oil-vapor particles. These particles are removed by the charcoal bed in the adsorber. After every 10,000 hours of compressor-unit operation, the adsorber must be replaced.

Because the pressure inside the housing of the compressor pump is that of the high-pressure supply gas, oil from the sump of the compressor pump is forced through the oil-to-air heat exchanger to cool the oil before it is mixed, for cooling purposes, with the low-pressure return-flow helium from the cold head. The high differential pressure across the metering orifice converts the oil on the high-pressure side (the sump side) of the orifice to minute particles of oil on the low-pressure side (the rotary-vane side). The metering orifice controls the rate of particulate-oil flow so as to provide optimum cooling of the rotary-vane compression device. The filter associated with the metering orifice prevents the orifice from becoming clogged with any foreign matter.

1.2.2.2 Pressure Regulation in the Compressor Unit (see Figure 1-5)

The compressor unit may be considered to be a fixed-speed, fixed-displacement pump that operates at an essentially constant temperature. The helium return and supply pressures of the compressor unit are thus governed by the cold head. However, a 185-psi differential-pressure relief valve is provided in the compressor unit in order to limit the operating pressure differential between the helium return and supply pressures of the compressor unit. When the differential pressure between the supply and return lines exceeds 185 + 5 psi, the differential-pressure relief valve opens. This passes helium gas to the low-pressure side, thereby reducing the load on the compressor pump. (It also allows the compressor unit to be run without operating the cold head.)

Since the cold head also is a fixed-displacement device, the helium supply and return pressures are determined by the cold-station temperatures. When the cold head is first started up, the cold stations are warm and therefore the density and mass-flow of the helium refrigerant are low. As a result, immediately following start-up, the pressure of the helium return gas is low and the pressure of the helium supply gas is high. As the temperatures of the cold stations decrease during cooldown, the density and mass-flow of the helium refrigerant increase. Under these conditions, the supply pressure progressively decreases slightly and the return pressure progressively increases slightly until the differential-pressure relief valve closes and stable operating pressure and a stable operating temperature are reached.

1.3 SPECIFICATIONS

The specifications for the compressor unit and cryopump of the CRYO-TORR(R) 8 High-Vacuum Pump are listed in Table 1-2.

1.4 CROSSOVER PRESSURE

The pressure in the User's vacuum chamber when the Hi-Vac valve (the high-vacuum isolation valve in the User's vacuum system; see Section 2.4) is opened (see Section 3.3) is called the crossover pressure. More specifically, the crossover pressure is defined as the pressure in the User's vacuum chamber at which the change (crossover) from rough-pumping the User's vacuum chamber with the User's rough-pumping system to high-vacuum-pumping that chamber with the cryopump takes place. The following equation can be used to determine the maximum permissible crossover pressure.

$$\text{Maximum Permissible Crossover Pressure} = \frac{\text{Maximum Gas Burst that can be Handled}}{\text{Volume of the User's Vacuum Chamber}}$$

The CRYO-TORR 8 High-Vacuum Pump can handle a maximum gas burst of 150 torr-liters from the User's vacuum chamber at crossover, if the composition of the residual gas in the User's vacuum chamber is primarily air. Thus, for example, with a typical 18-inch-diameter x 30-inch-high bell jar, which has a volume of about 100 liters, the maximum permissible crossover pressure would be

$$\frac{150 \text{ torr-liters}}{100 \text{ liters}} = 1.5 \text{ torr} = 1{,}500 \text{ microns}$$

Note: If the composition of the residual gas in the User's vacuum chamber is not known, it is wise to assume (in applying the above equation for determining the maximum permissible crossover pressure for the initial start-up and cooldown) that the maximum gas burst that can be handled is well below 150 torr-liters. Then, during subsequent crossovers, gradually increase the crossover pressure while noting the response of the hydrogen-vapor-pressure gauge. When the Hi-Vac valve is opened, the hydrogen-vapor-pressure gauge will peak. This peak should not exceed 25 psia (22K). This is to ensure that the 15K and 80K condensing arrays do not warm above the point at which they would release previously condensed gases that have been frozen onto these arrays.

1.5 TEMPERATURE INDICATION

When the second-stage cold station (9, Figure 1-2) is at a temperature of 24K or below, its temperature may be measured by means of the hydrogen-vapor-pressure gauge on the cryopump. Use the data given in Table F-1 of Appendix F to convert a reading of the hydrogen-vapor-pressure gauge (in psia) to temperature (in Kelvin).

The CRYO-TORR™ Vacuum-Pump Temperature Indicator is available as an optional accessory to read the temperature of the second-stage cold station when the cryopump is equipped with the optional silicon-diode temperature sensor.

TABLE 1-1. FEATURES OF THE MODEL 350SC COMPRESSOR UNIT

FEATURE	FIGURE 1-4 ITEM NO.	FUNCTION
Compressor-Unit "ON-OFF" Switch (SW1)	1	Starts and stops the compressor pump and cooling fan. The switch contains a built-in circuit breaker to protect the system from excessive current drain.
Cold-Head "ON-OFF" Switch (SW3)	2	Starts and stops the cold-head drive motor, once the compressor-unit "ON-OFF" switch has been activated.
Elapsed-Time Meter (ETM)	3	Indicates, in hours, the cumulative compressor-unit operating time.
Input Power Cable	4	Connects the compressor unit to its power source.
Cold-Head Power Cable	5	Provides power to the cold-head drive motor.
GAS CHARGE Fitting	6	Used to adjust the compressor unit charge pressure. When additional pressure is required, a source of helium gas may be connected to this fitting -- which is located on the supply (high)-pressure side of the compressor unit.
Helium supply PRESSURE gauge	7	Indicates the pressure of the helium supply gas.
Helium RETURN GAS connector	8	Self-sealing coupling for connecting the helium return line from the cryopump to the compressor unit.
Helium SUPPLY GAS connector	9	Self-sealing coupling for connecting the helium supply line from the compressor unit to the cryopump.
Safety interlock switch (SW2)	-	Ensures that the compressor unit can not be inadvertently turned on when its cover is not in place.

Note: The symbol designations given in parentheses for the electrical controls and indicators are those used on the electrical schematic diagram shown in Figure B-1 of Appendix B.

TABLE 1-2. SPECIFICATIONS FOR THE CRYO-TORR(R) 8 HIGH-VACUUM PUMP

MODEL 350SC COMPRESSOR UNIT

Dimensions (approximate)	
Length	19.6 inches (498 mm)
Width	19.5 inches (495 mm)
Height	16.8 inches (426 mm)
Weight (approximate)	140 pounds (63.5 kg)
Power requirements	
Part Number D8032028G1	208 or 230 VAC, 60 Hz, single phase; 11 amps max while unit is running. The recommended operating voltage range is 198 volts (minimum) to 253 volts (maximum).
Part Number D8032028G2	200 or 220 VAC, 50 Hz, single phase; 11 amps max while unit is running. The recommended operating voltage range is 190 volts (minimum) to 230 volts (maximum).
	Notes: (1) Each recommended voltage range applies to the voltage across the "run" terminals of the compressor-pump motor (see Figure B-1).
	(2) The nominal operating power requirement for each unit is 1.5 kW.
Helium Pressures	
Static Pressure	250 +0, -5 psig (at ambient temperature)
Supply Pressure (normal operation)	270-290 psig (at operating temperature)
Ambient-temperature Range	60°F to 100°F (16°C to 38°C)
Interface	
Length of power supply cable	10 feet (3m)
Length of cold-head power cable	10 feet (3m)
Power-supply-cable connector	2-pole, 3-wire, grounded, NEMA 6-15R
Gas-supply connector	1/2-inch self-sealing coupling
Gas-return connector	1/2-inch self-sealing coupling
Adsorber service schedule	Replace at 10,000 hours of use

TABLE 1-2. SPECIFICATIONS FOR THE CRYO-TORR(R) 8 HIGH-VACUUM PUMP (cont.)

CRYO-TORR(R) 8 CRYOPUMP	
Weight (approximate)	45 lbs (20.4 kg)
Power requirement	150 VAC, 1Ø (supplied from the compressor unit)
Instrumentation	
Hydrogen-vapor-pressure gauge charge pressure at 70°F (21°C) and 14.7 psi (1 kg/cm)	80 ± 2 psia
Interface	
Gas-supply connector	1/2-inch self-sealing coupling
Gas-return connector	1/2-inch self-sealing coupling
Pumping speeds	
Water	4,000 liters/second
Air	1,500 liters/second
Hydrogen	2,000 liters/second
Argon	1,200 liters/second
Argon throughput (maximum)	700 scc/minute; 8.9 torr-liters/second. (A throttling valve is required for pressures exceeding $5x10^{-3}$ torr.)
Orientation	The cryopump may be operated in any orientation.

LEGEND FOR FIGURE 1-2

Item Number	Description
1	80K Condensing Array (First-Stage Array Assembly)
2	15K Condensing Array (Second-Stage Array Assembly)
3	15K Cryo-Adsorbing Array (also known as the 15K Inner Charcoal Chamber)
4	80K Radiation Shield
5	Cold-Head Cylinder
6	First-Stage Cylinder
7	First-Stage Cold Station
8	Second-Stage Cylinder
9	Second-Stage Cold Station
10	O-Ring Between the Drive Unit - Displacer Assembly and the Vacuum Housing
11	Protective Cover
12	Inlet-Seal O-Ring
13	Mounting Flange
14	Hydrogen-Vapor-Pressure Gauge (Thermometer)*
15	End Plate
16	Shell
17	Vacuum Housing
18	Relief Valve Assembly
19	Cold Head (Refrigerator Unit)
20	Helium-Gas Supply Connector
21	Helium-Gas Return Connector
22	Electrical Power Connector for the Cold Head
23	Drive Unit
24	Drive Motor
25	Driver Mechanism
26	Crankcase
27	Sight Glass
28	Displacer-Regenerator Assembly
29	Accessory Port
30	Accessory-Port Cover

*The CRYO-TORR 8 Cryopump is also available with a silicon-diode temperature sensor.

NOTES:

1. See also Figure A-1 in Appendix A, which shows the CRYO-TORR(R) 8 Cryopump disassembled into its major component assemblies.
2. The cold-head cylinder (5), which consists of items 6 through 9, contains the two-stage displacer-regenerator assembly shown in Figure 1-3.
3. The vacuum housing, which consists of items 5, 13, 15, 16, and 18, appears in Figure A-1 of Appendix A as item 34.
4. The drive unit (23) consists of items 24 through 27.
5. The displacer-regenerator assembly (28), which is located inside the cold-head cylinder (5), consists of two displacer-regenerator stages (see Figure 1-3).
6. The drive unit (23) and the displacer-regenerator assembly (28), the helium-gas connectors (20) and (21), and the electrical power connector (22), constitute the drive unit-displacer assembly shown in Figure 1-3 and also as item 26 in Figure A-1 of Appendix A.
7. The cold head (19) consists of items 5, 20, 21, 22, 23, and 28; or, stated another way, the cold head consists of the drive unit-displacer assembly shown in Figure 1-3 plus the cold-head cylinder (5).

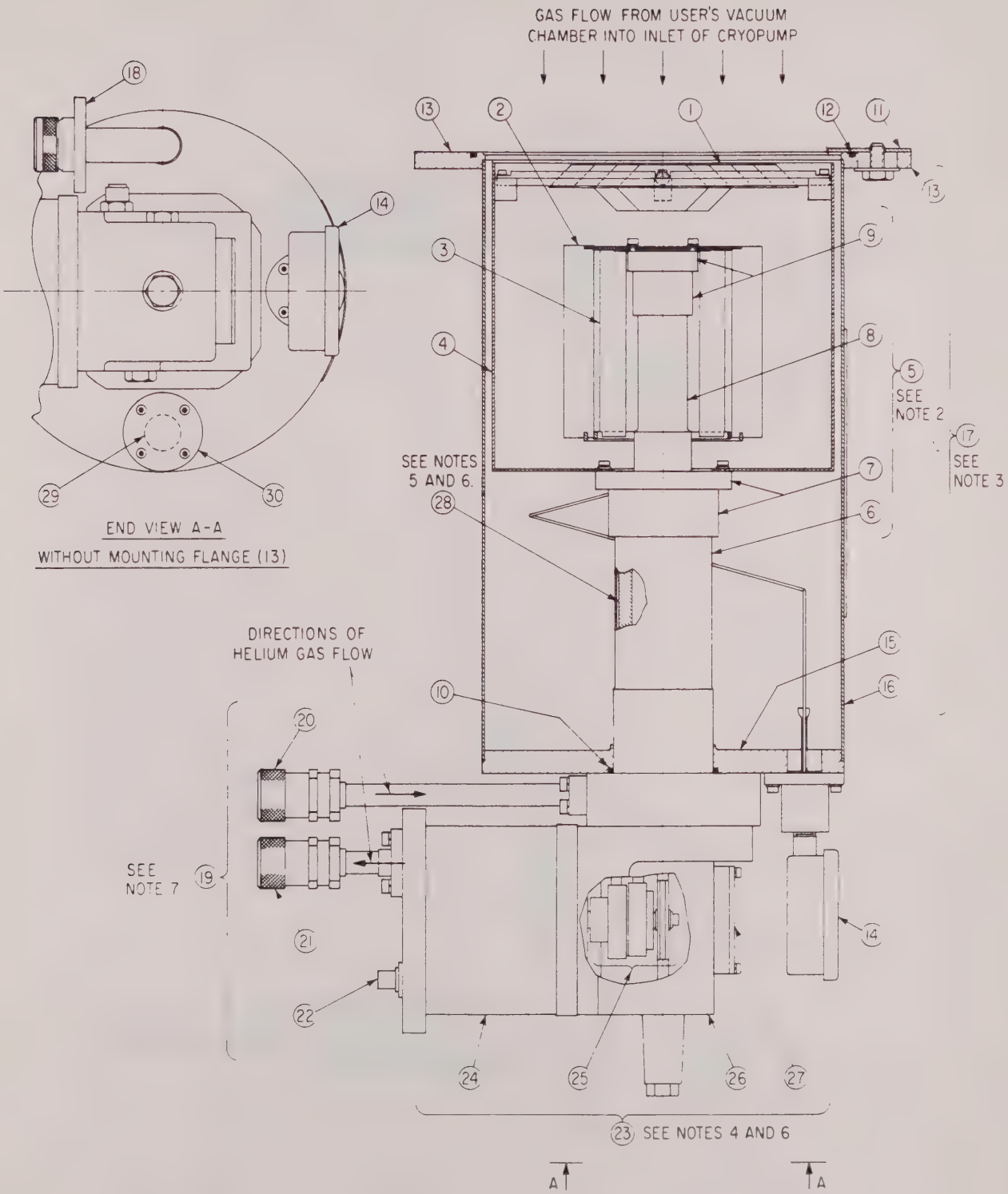

GAS FLOW FROM USER'S VACUUM CHAMBER INTO INLET OF CRYOPUMP
END VIEW A-A
WITHOUT MOUNTING FLANGE (13)
SEE NOTES 5 AND 6.
SEE NOTE 2
SEE NOTE 3
DIRECTIONS OF HELIUM GAS FLOW
SEE NOTE 7
23 SEE NOTES 4 AND 6
A
A

FIGURE 1-2. CROSS SECTION OF THE CRYO-TORR® 8 CRYOPUMP

LEGEND FOR FIGURE 1-3

Item Number	Description
1	Sight Glass
2	Crank Case (houses the drive mechanism)
3	Drive Motor
4	Electrical Power Connector
5	Helium-Gas Return Connector
6	Helium-Gas Supply Connector
7	Pressure Relief Valve
8	Displacer-Regenerator Assembly
9	First-Stage Displacer-Regenerator
10	Second-Stage Displacer-Regenerator

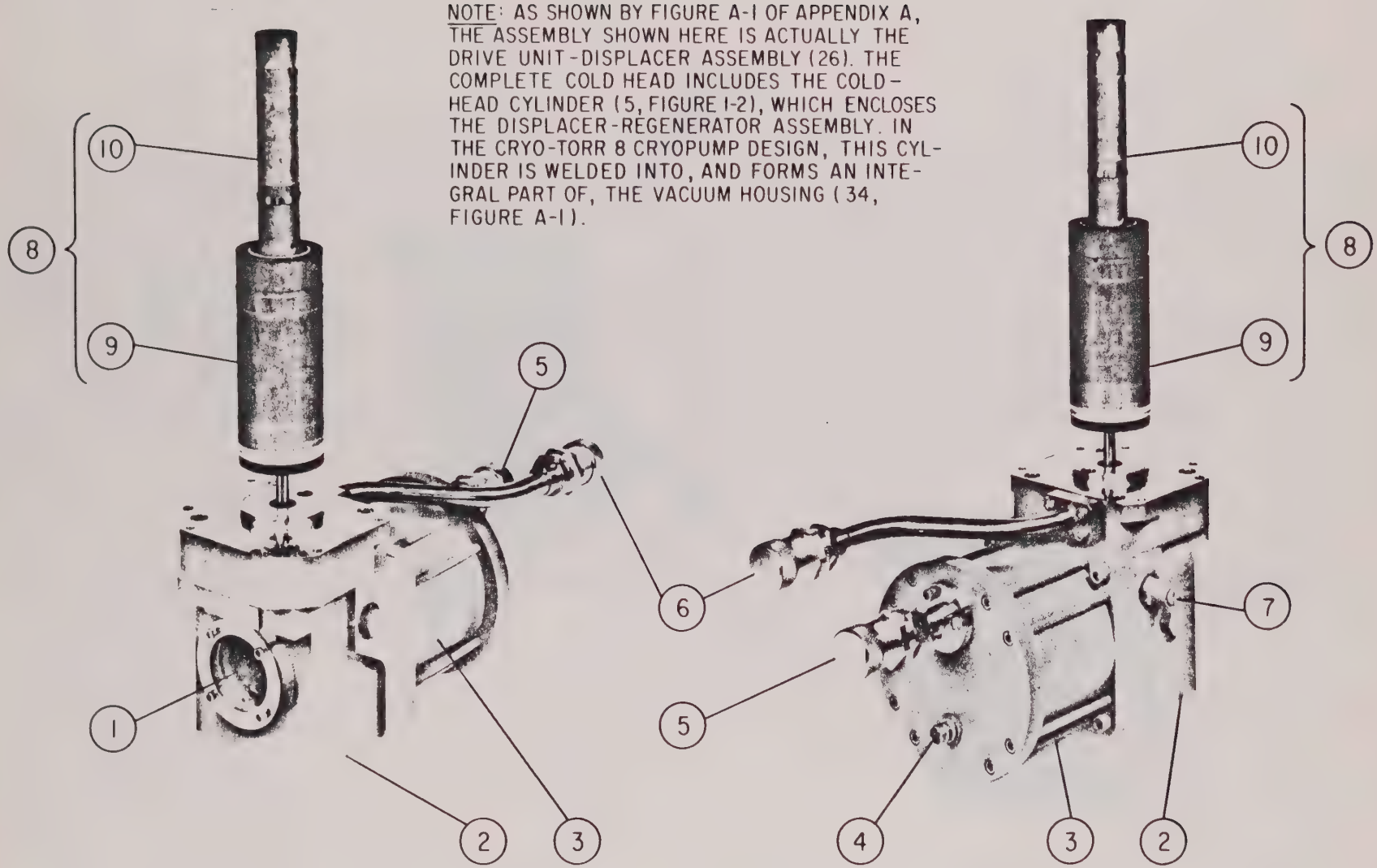
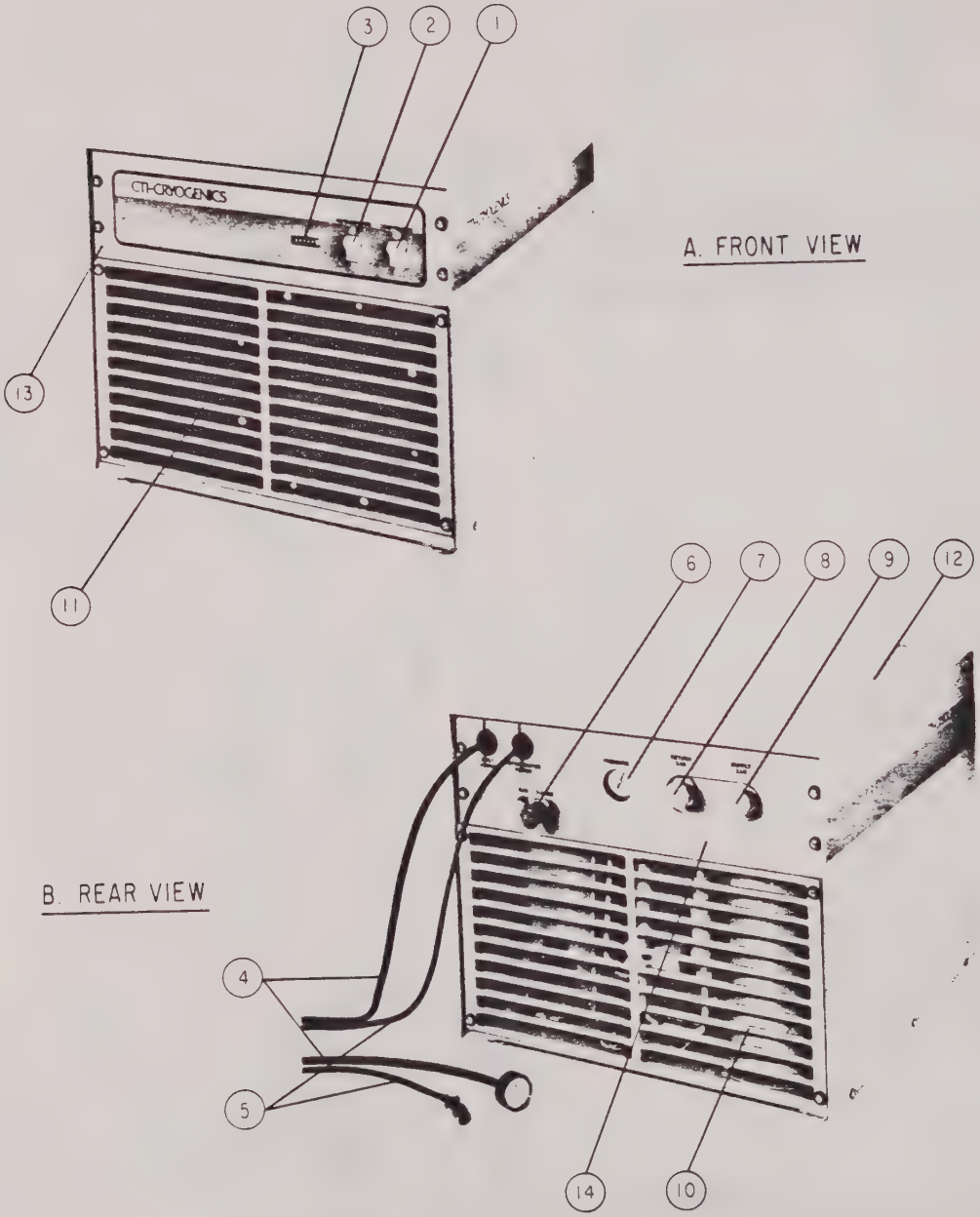

NOTE: AS SHOWN BY FIGURE A-1 OF APPENDIX A, THE ASSEMBLY SHOWN HERE IS ACTUALLY THE DRIVE UNIT-DISPLACER ASSEMBLY (26). THE COMPLETE COLD HEAD INCLUDES THE COLD-HEAD CYLINDER (5, FIGURE 1-2), WHICH ENCLOSES THE DISPLACER-REGENERATOR ASSEMBLY. IN THE CRYO-TORR 8 CRYOPUMP DESIGN, THIS CYLINDER IS WELDED INTO, AND FORMS AN INTEGRAL PART OF, THE VACUUM HOUSING (34, FIGURE A-1).
10
8
9
5
6
1
2
3
A. FRONT VIEW
10
8
9
7
5
4
3
2
B. REAR VIEW

FIGURE 1-3. THE COLD HEAD (LESS CYLINDER) OF THE CRYO-TORR® 8 CRYOPUMP



LEGEND

1 COMPRESSOR-UNIT "ON-OFF" SWITCH
2 COLD-HEAD "ON-OFF" SWITCH
3 ELAPSED-TIME METER (ETM)
4 INPUT POWER CABLE
5 COLD-HEAD POWER CABLE
6 GAS CHARGE FITTING
7 SUPPLY PRESSURE GAUGE
8 GAS-RETURN CONNECTOR
9. GAS-SUPPLY CONNECTOR
10. REAR GRILLE
11. FRONT GRILLE
12. COVER
13. FRONT PANEL
14. REAR PANEL

FIGURE 1-4 THE MODEL 350SC COMPRESSOR UNIT

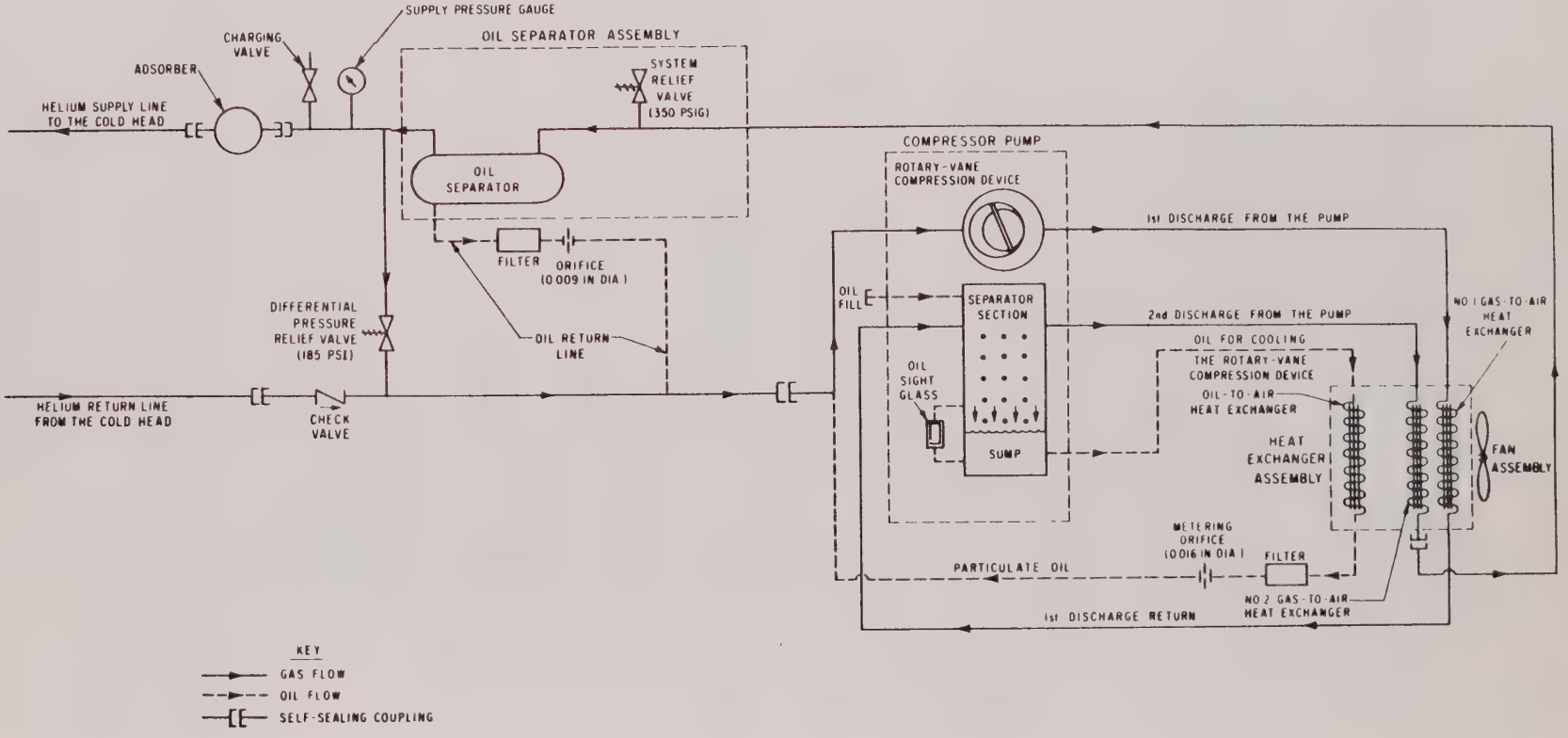


FIGURE 1-5. FLOW DIAGRAM FOR THE MODEL 350SC COMPRESSOR UNIT

CHAPTER 2
INSPECTION AND INSTALLATION

2.1 GENERAL

The components of the CRYO-TORR(R) 8 High-Vacuum Pump should already have been inspected for external evidence of damage incurred in shipping. If this has not been done, do so now. If evidence of damage is found, notify the shipper at once.

CAUTIONS: (1) WHEN CONNECTING OR DISCONNECTING A SELF-SEALING COUPLING, ALWAYS USE TWO WRENCHES (SUPPLIED) TO AVOID LOOSENING THE BODY OF THE COUPLING FROM ITS ADAPTER. FOR EXAMPLE, SEE FIGURES 2-3 AND 6-3.

(2) ALWAYS CHECK THAT THE FLAT RUBBER GASKET IS IN PLACE BEFORE CONNECTING A SELF-SEALING COUPLING.

(3) NEVER CONNECT OR DISCONNECT A SELF-SEALING COUPLING WHEN IT IS UNDER VACUUM. TO DO SO WILL CONTAMINATE THE ASSOCIATED COMPONENTS.

(4) DECONTAMINATE (IN ACCORDANCE WITH SECTION 6.4) ANY COMPONENT THAT HAS LOST ITS HELIUM CHARGE, PRIOR TO CONNECTING THE COMPONENT INTO THE HIGH-VACUUM PUMP.

Note: For an understanding of the structure of a self-sealing coupling, see the cutaway views that are shown in Figure 6-2.

2.2 CRYOPUMP INSPECTION

Inspect these parts of the cryopump for evidence of damage:

(1) The exterior of the vacuum housing (17, Figure 1-2) and the cold head (19).

(2) The hydrogen-vapor-pressure gauge (14). This gauge should indicate 80 ± 2 psia.

(3) The louver assembly that comprises the 80K condensing array (1). Remove the protective cover (11) to inspect this assembly, which is located just inside the inlet of the vacuum housing.

(4) The mounting flange (13) and its O-ring groove.

CAUTION: REPLACE THE PROTECTIVE COVER UNLESS THE CRYOPUMP IS GOING TO BE INSTALLED IMMEDIATELY (SEE SECTION 2.4).

2.3 INTERCONNECTING-PIPING INSPECTION

Inspect the interconnecting piping for evidence of damage. In particular, look for kinks or broken strands in the outer braid.

The self-sealing couplings are shipped with dust caps and dust plugs in place. Do not remove these caps and plugs until the interconnecting piping is to be connected to the components of the high-vacuum pump (see Section 2.7).

> *CAUTION: DO NOT BEND THE FLEXIBLE INTERCONNECTING PIPING TO LESS THAN A SIX-INCH RADIUS OR DAMAGE MAY OCCUR. ALSO, AVOID TWISTING THE PIPING WHEN MAKING FINAL CONNECTIONS.*

2.4 CRYOPUMP INSTALLATION

The major interface dimensions of the CRYO-TORR(R) 8 Cryopump are shown in Figure 2-2. This cryopump may be installed in any orientation.

If possible, a high-vacuum isolation valve (commonly referred to as the Hi-Vac valve) should be installed between the cryopump and the User's vacuum chamber. This valve will isolate the cryopump from the User's vacuum chamber during preliminary vacuum pumping (rough-pumping), cooldown, and regeneration. It will also assist in troubleshooting. If no Hi-Vac valve is installed, the 15K inner charcoal chamber (3, Figure 1-2 and 5, Figure A-1 of Appendix A) may become heavily loaded during the cooldown process. This will result in lower pumping speeds for helium, hydrogen, and neon. Also, the cryopump will probably have to be regenerated more frequently.

It is recommended that the User install a high-vacuum gauge, capable of measuring vacuums to 10^{-8} torr or better, in the Hi-Vac valve in order to monitor the cryopump's performance when the Hi-Vac valve is closed.

The mounting flange on the vacuum housing is designed to mate with a 6-inch ANSI flanged connection. If some other mating connection is to be used, be sure that the inside diameter of that connection is at least 1/4 inch smaller than the inside diameter of the inlet O-ring groove (8 1/4-inch ID) on the cryopump. If the mating connection also has an O-ring groove, it will be necessary to interpose a double-sided, flat-faced ring at the interface.

> Note: As discussed in Section 1.2.1.1, an accessory port (29, Figure 1-2) is provided on the vacuum housing to enable a roughing valve and/or a vacuum gauge to be connected to the housing.

Install the cryopump as follows:

(1) Remove the protective cover (11, Figure 1-2).

(2) Remove and discard the inlet-seal O-ring (12) that was installed for shipment. Failure to replace the inlet-seal O-ring may be a potential source of vacuum leaks.

(3) Remove from its package the new inlet-seal O-ring that is supplied. Wipe the O-ring clean with a lint-free cloth or towel. Then sparingly lubricate it with low-vapor-pressure grease; for example, Apiezon "L" grease.

CAUTION: KEEP THE USE OF VACUUM-SYSTEM LUBRICANTS TO A MINIMUM TO AVOID CONTAMINATING THE VACUUM SYSTEM.

(4) Install the new inlet-seal O-ring.

(5) Bolt the cryopump to the User's flange. Tighten the mounting bolts evenly to ensure uniform compression of the O-ring and to prevent flange distortion. The final bolt torque should not exceed 20 ft-lb.

WARNING: THE RELIEF VALVE ASSEMBLY (18) ON THE VACUUM HOUSING (17) NORMALLY VENTS DIRECTLY TO THE ATMOSPHERE. IF THE CRYOPUMP IS TO BE USED WITH TOXIC, CORROSIVE, OR FLAMMABLE GASES, HOWEVER, CONNECT A VENT PIPE TO THE FLANGE ON THE RELIEF VALVE ASSEMBLY AND VENT THESE GASES TO A SAFE LOCATION. CARE MUST BE TAKEN IN MAKING THIS CONNECTION. A SUITABLE ADAPTER CAN BE FABRICATED BY USING VIEW B-B OF CTI-CRYOGENICS DRAWINGS E8033036 AND E8033047 (SEE APPENDIX G). THE 1.30-INCH-DIAMETER x 1.38-INCH-LONG VOLUME AROUND THE RELIEF VALVE MUST REMAIN CLEAR.

2.5 COMPRESSOR-UNIT INSPECTION (see Figure 1-4)

(1) Inspect the exterior of the compressor unit for shipping damage.

(2) Check the compressor-unit supply pressure gauge (7, Figure 1-4). It should indicate 260 ± 10 psig, or slightly higher if the compressor unit has been stored in a warm location.

Notes: (1) If the supply pressure gauge indicates zero pressure, assume that the compressor unit is contaminated. Pressurize the compressor unit in accordance with Section 6.3 and look for the leak. After repairing the leak, decontaminate the compressor unit in accordance with Section 6.4.2. Consult the Product Service Department of CTI-CRYOGENICS if there are any questions.

(2) Compressor units are shipped in an overcharged condition to allow for some loss of gas while connecting the unit. Instructions for adjusting the gas pressure to its proper value are given in Sections 2.7 and 6.3.

(3) Remove the rear grille (10).

(4) Using a flashlight, inspect the interior of the compressor unit for evidence of damage or oil loss.

(5) Check the oil level in the sight glass on the compressor pump. This level must be visible.

CAUTION: IF NO OIL IS VISIBLE, CONSULT THE PRODUCT SERVICE DEPARTMENT OF CTI-CRYOGENICS BEFORE PROCEEDING.

2.6 COMPRESSOR-UNIT PREPARATION AND INSTALLATION

Notes: (1) The compressor unit must be installed right-side-up on a surface that deviates from a level plane by no more than 10 degrees.

(2) The electrical-control panel and chassis located at the front of the compressor unit can be removed and mounted on a standard 19-inch rack. Such an installation will require modification of the cables from the electrical-control chassis to the compressor unit and the cryopump.

Proceed with the preparation and installation of the compressor unit as follows.

(1) Install the compressor unit so that the minimum clearance at the front and at the back is 12 inches (30 cm).

CAUTION: THIS MINIMUM CLEARANCE MUST BE PROVIDED IN ORDER TO ENSURE AN ADEQUATE FLOW OF AIR THROUGH THE COMPRESSOR UNIT. OTHERWISE, THE UNIT WILL OVERHEAT AND SHUT DOWN.

WARNING: ENSURE THAT BOTH OF THE SWITCHES ON THE FRONT OF THE COMPRESSOR UNIT ARE OFF BEFORE CONNECTING THE COMPRESSOR UNIT TO ITS POWER SOURCE.

(2) Plug the input power cable (4, Figure 1-4) into the power source. The power requirement for your compressor unit is given in Table 1-2.

(3) Turn the compressor unit on and leave it on for 15 minutes. (During this time, the gas will pass through the internal pressure-bypass valve). The purpose of this preliminary run is to return to the compressor-pump sump any oil that might have accumulated in the internal lines during shipment.

(4) Check that the fan is operating, and that air is drawn in through the fan and blows over the compressor pump before exhausting at the rear of the compressor unit.

(5) Check that the oil level is visible in the sight glass.

CAUTION: IF NO OIL IS VISIBLE, CONSULT THE PRODUCT SERVICE DEPARTMENT OF CTI-CRYOGENICS BEFORE PROCEEDING.

(6) Turn off the compressor unit and allow it to cool down, so that the adsorber can be connected.

WARNING: DISCONNECT THE COMPRESSOR UNIT FROM ITS POWER SOURCE BEFORE CONNECTING THE ADSORBER.

Note: The compressor unit is shipped from the factory with the adsorber installed but disconnected from the internal piping, in order to prevent any possibility of contaminating the charcoal in the adsorber with oil during shipment of the compressor unit. Failure to connect the adsorber will result in no helium flowing to the cold head and therefore no cryopumping.

(7) Remove the dust cap and the dust plug, respectively, from the self-sealing coupling half at the adsorber inlet and the mating self-sealing coupling half on the internal helium supply line. (This self-sealing coupling is located internally at the rear of the compressor unit; see Figure 2-3).

(8) Using the special wrenches supplied (see Appendix D), carefully connect the helium-supply-line coupling half to the adsorber-inlet coupling half (see Figure 2-3). Be sure the coupling is firmly seated but do not apply more than 35 foot-pounds of torque.

CAUTION: WHEN CONNECTING A SELF-SEALING COUPLING, ALWAYS USE TWO WRENCHES AND CHECK THAT THE FLAT RUBBER GASKET IS IN PLACE; SEE SECTION 2.1.

(9) Replace the rear grille on the compressor unit.

2.7 COMPONENT INTERCONNECTIONS

A component interconnection diagram for the CRYO-TORR(R) 8 High-Vacuum Pump is shown in Figure 2-1.

CAUTION: DO NOT CONNECT THE COMPRESSOR UNIT TO ITS POWER SOURCE UNTIL ALL INTERCONNECTIONS HAVE BEEN MADE AS FOLLOWS BETWEEN THE COMPONENTS OF THE HIGH-VACUUM PUMP. THIS WILL PRECLUDE THE POSSIBILITY OF HARMFUL ELECTRICAL DISCHARGES OCCURRING ACROSS EITHER ELECTRICAL CONNECTIONS OR PIPING CONNECTIONS WHILE THE COMPONENT INTERCONNECTIONS SHOWN IN FIGURE 2-1 ARE BEING MADE.

Note: The User's rough-pumping system that is depicted in Figure 2-1 is discussed in Section 3.2.

Proceed as follows with the component interconnections and related procedures.

(1) Remove the dust caps from the gas-supply and gas-return connectors on the cold head and on the rear of the compressor unit.

(2) Connect the interconnecting piping between the compressor unit and the cold head (see Figure 2-1) as specified below.

CAUTIONS: (1) IF A SELF-SEALING COUPLING STARTS TO LEAK, SCREW THE COUPLING HALVES TOGETHER FASTER.

(2) ALWAYS CONNECT THE PIPING TO THE COMPRESSOR UNIT FIRST AND THEN TO THE COLD HEAD. OTHERWISE, THERE IS DANGER OF INTRODUCING CONTAMINATION.

(a) Connect the helium return line to the gas-return connector (8, Figure 1-4) on the rear of the compressor unit.

(b) Connect the helium supply line to the gas-supply connector (9) on the rear of the compressor unit.

(c) Connect the helium supply line to the gas-supply connector (6, Figure 1-3) on the cold head.

(d) Connect the helium return line to the gas-return connector (5) on the cold head.

(3) Read the pressure on the compressor-unit supply pressure gauge. The desired static pressure is 250 +0, -5 psig at 75°F.

Note: Ensure that the compressor unit is in the ambient-temperature operating range (60°F to 100°F; 16°C to 38°C) before making this reading.

(4) If the indicated pressure is lower than 245 psig, add helium gas as described in Section 6.3.

Note: If the static pressure is below 240 psig, the performance of the cryopump may be less than shown in the specifications of Table 1-2.

(5) If the indicated pressure is higher than 250 psig, reduce the pressure as follows:

(a) Remove the flare cap from the gas charge fitting (6, Figure 1-4) on the rear of the compressor unit.

(b) While observing the supply pressure gauge, very slowly (and only slightly) open the gas charge valve and reduce the gauge indication to 250 psig.

(c) Close the gas charge valve after the correct charge pressure has been obtained, and reinstall the flare cap.

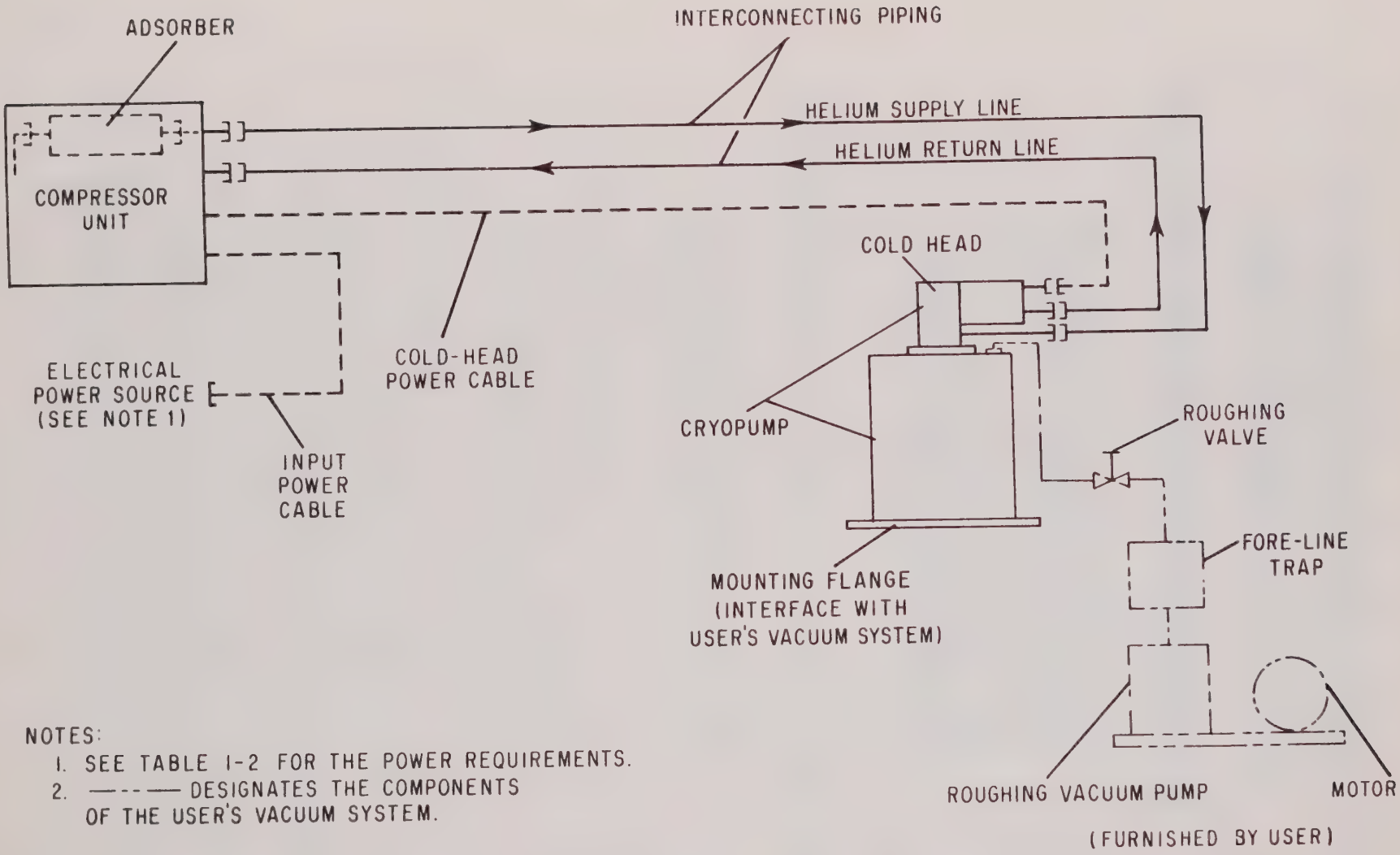
(6) Connect the cold-head power cable (5, Figure 1-4) of the compressor unit to the power connector (4, Figure 1-3) of the cold head.

CAUTION: NEVER CONNECT THE COLD-HEAD POWER CABLE TO THE COLD HEAD WHILE THE COMPRESSOR UNIT IS RUNNING. THIS WILL PRECLUDE THE POSSIBILITY OF HARMFUL ELECTRICAL DISCHARGES OCCURRING ACROSS THE ELECTRICAL CONNECTIONS.

(7) With the two "ON-OFF" switches of the compressor unit (1 and 2, Figure 1-4) switched off, plug the input power cable (4, Figure 1-4) into the power source. (See Table 1-2 for the applicable power requirements.)

WARNING: ENSURE THAT BOTH OF THE SWITCHES ON THE FRONT OF THE COMPRESSOR UNIT ARE OFF BEFORE CONNECTING THE COMPRESSOR UNIT TO ITS POWER SOURCE.

Note: Do not switch these two switches on until commencing the start-up and cooldown procedures; see Section 3.3.



NOTES:

1. SEE TABLE 1-2 FOR THE POWER REQUIREMENTS.
2. —- - - — DESIGNATES THE COMPONENTS OF THE USER'S VACUUM SYSTEM.

FIGURE 2-1. COMPONENT INTERCONNECTION DIAGRAM FOR THE CRYO-TORR® 8 HIGH-VACUUM PUMP

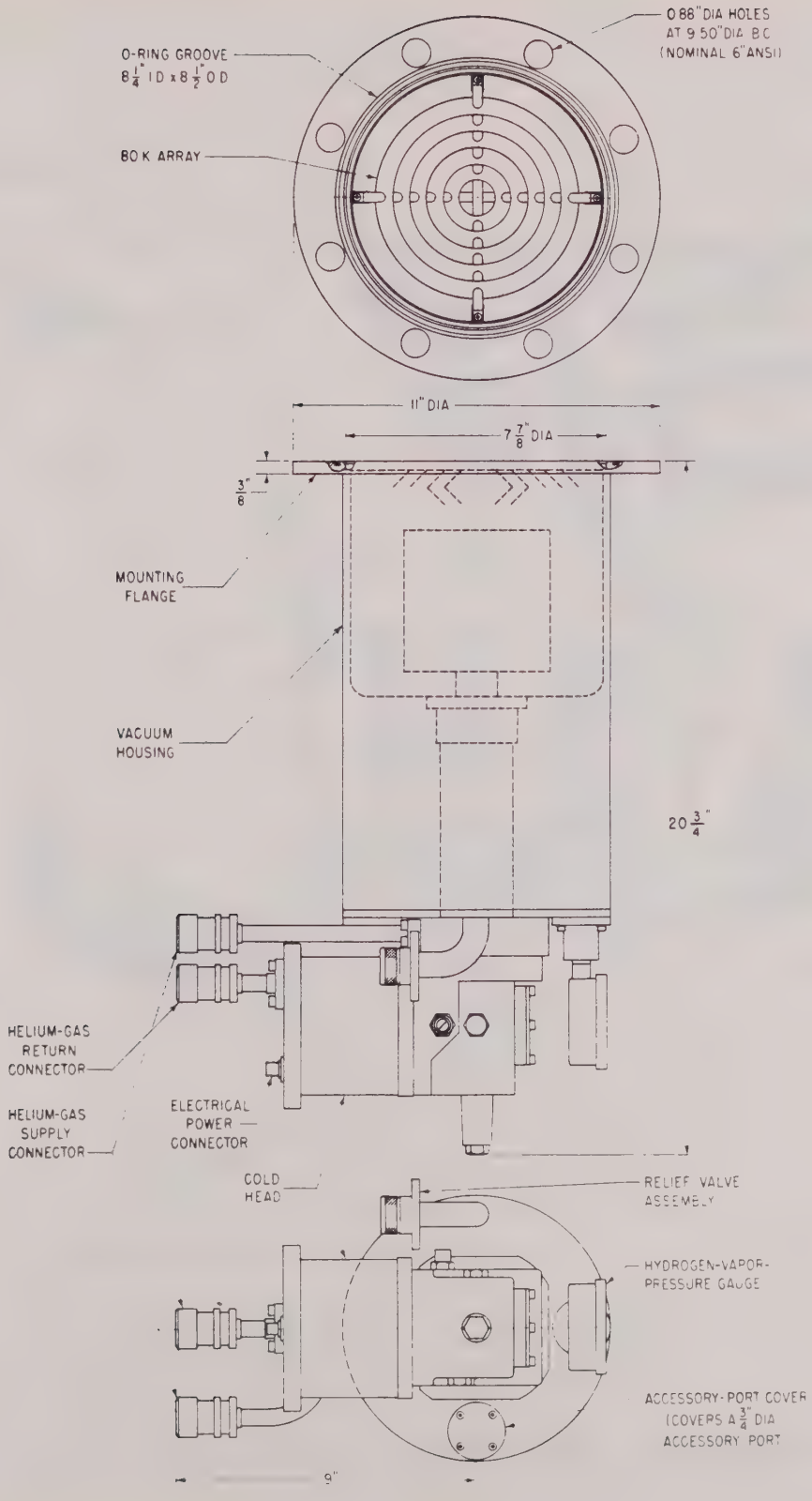
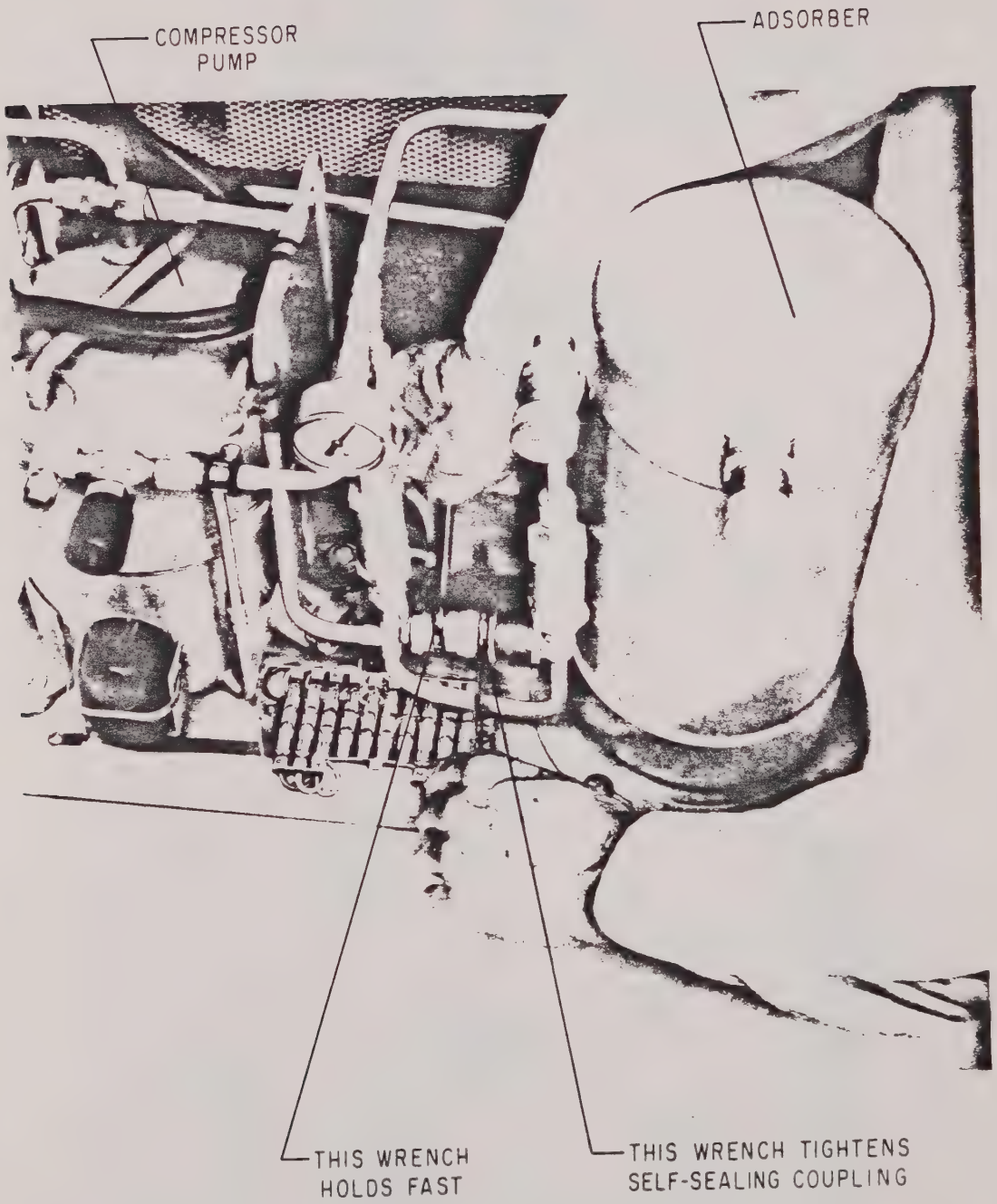


FIGURE 2-2. THE INSTALLATION INTERFACE OF THE CRYO-TORR® 8 CRYOPUMP



NOTE: THE COVER HAS BEEN REMOVED FOR THE SAKE OF CLARITY. ONLY THE REAR GRILLE HAS TO BE REMOVED IN ORDER TO CONNECT THE ADSORBER.

FIGURE 2-3. CONNECTING THE ADSORBER IN THE MODEL 350SC COMPRESSOR UNIT

CHAPTER 3
OPERATION

3.1 GENERAL

The following instructions assume that the CRYO-TORR(R) 8 High-Vacuum Pump has been properly interfaced with the User's vacuum system (see Section 2.4).

Prior to start-up ensure that:

(1) The component interconnections have been made (see Section 2.7).

(2) The adsorber has been connected into the compressor unit (see Section 2.6).

> Note: Failure to connect the adsorber will result in no helium flowing to the cold head and therefore no cryopumping.

(3) The various checks listed in Chapter 2 have been made.

(4) The cryopump is at room temperature and at atmospheric pressure.

(5) The supply pressure gauge on the rear of the compressor unit indicates a static pressure of 250 +0, -5 psig at 75°F.

(6) A vacuum gauge has been installed in the roughing line (see Figure 2-1) to monitor cryopump response during evacuation.

> Note: It is important to maintain an operating log, especially when operating the CRYO-TORR 8 High-Vacuum Pump for the first time or in a new installation. Readings of the hydrogen-vapor-pressure gauge and the compressor-unit supply pressure gauge should be recorded every 6 minutes during the initial cooldown. A set of these readings should be taken once a day while the high-vacuum pump is operating under normal load conditions. These records may be extremely useful later, both in recognizing degradation of performance and in troubleshooting.

3.2 PRELIMINARY VACUUM PUMPING (ROUGH-PUMPING)

> *CAUTION: DURING ROUGH-PUMPING, BACKSTREAMING OF MECHANICAL-PUMP OIL SHOULD BE MINIMIZED BY USING A MOLECULAR-SIEVE FORE-LINE TRAP (SEE FIGURE 2-1).*

(1) Ensure that the conditions noted in steps 1 through 6 of Section 3.1 have been met.

(2) Using a mechanical pump, rough-pump the cryopump to a pressure of 50 microns. When a new cryopump has been installed into the User's vacuum system, the initial evacuation may take longer than usual because of moisture in the 15K inner charcoal chamber.

CAUTION: DO NOT ROUGH-PUMP THE CRYOPUMP ANY LONGER THAN IS NECESSARY TO SATISFY STEPS 3 AND 4 BELOW.

Note: If no Hi-Vac valve (see Section 2.4) is installed between the cryopump and the User's vacuum chamber, it may be impossible to attain the desired 50-micron vacuum. In this case, the vacuum in the User's vacuum chamber should be reduced to as low a level as possible.

(3) Close the roughing valve and note the rate at which pressure rises in the cryopump. If the rate is 10 microns/minute or less, start the cryopump.

(4) If the rate is greater than 10 microns/minute, repeat steps 1 and 2.

Note: If the pump-down takes a long time, refer to the cryopump troubleshooting procedures provided in Table 5-1.

3.3 START-UP AND COOLDOWN

(1) Rough-pump the cryopump in accordance with Section 3.2.

CAUTION: NEVER LEAVE THE ROUGHING VALVE OPEN WHEN THE CRYOPUMP IS OPERATING. OIL FROM THE MECHANICAL PUMP COULD BACKSTREAM AND CONTAMINATE THE CHARCOAL IN THE CRYOPUMP.

(2) Record in the operating log the readings of the hydrogen-vapor-pressure gauge, the compressor-unit supply pressure gauge, and the elapsed-time meter.

(3) Switch on the compressor-unit "ON-OFF" switch (1, Figure 1-4).

(4) Switch on the cold-head "ON-OFF" switch (2).

(5) Record the compressor-unit supply pressure, the hydrogen vapor pressure, and, if possible, the vacuum reading of the cryopump every 6 minutes during the initial cooldown.

(6) With the Hi-Vac valve closed, the cryopump should achieve a second-stage-cold-station temperature of 20K or less (15 psia or less on the hydrogen-vapor-pressure gauge) in approximately 90 minutes. (If the Hi-Vac valve is open to the User's vacuum chamber, a cooldown to this temperature range will take longer.)

Note: If the cryopump is not cryogenically cold (as indicated by a reading of the hydrogen-vapor-pressure gauge that is 46 psia or less) or has not achieved an insulating vacuum of 10^{-3} torr or better by 2-1/2 hours, refer to the cryopump troubleshooting procedures provided in Table 5-1.

(7) Rough-pump the User's vacuum chamber to a suitable crossover pressure (see Section 1.4).

(8) Close the roughing valve.

(9) Open the Hi-Vac valve.

Table 3-1 indicates typical ranges of pressure variations (including hydrogen-vapor-pressure readings) with time during cooldowns. The values listed are dependent upon the heat load of the cold head. Pressure regulation during cooldown is automatic (see Section 1.2.2.2).

TABLE 3-1. TYPICAL PRESSURE VARIATIONS DURING COOLDOWNS AND DURING NORMAL OPERATION

Time	Helium Supply Pressure (psig)	Helium Return Pressure* (psig)	Hydrogen Vapor Pressure (psia)
Prior to start-up	245-250	245-250	80
10 mins. after start-up	270-290	85-105	80
45 mins. after start-up	270-290	90-110	75
1 hour after start-up	270-290	95-115	70
2 hours after start-up	270-290	110-130	Less than 15
During Normal Operation	270-290	110-130	0-10

Note: The ultimate vacuum level of the cryopump is in the middle of the 10^{-8} torr range. This level is not affected by the cold-head temperature unless the reading of the hydrogen-vapor-pressure gauge is above 12 psia. Should this condition exist, check the entire system to determine the cause.

*A gauge is not supplied to read the helium return pressure but one can be installed in the return line by using an optional "charging tee".

3.4 NORMAL OPERATION

The components of the CRYO-TORR(R) 8 High-Vacuum Pump are designed to operate unattended under normal conditions. The values given in Table 3-1 for normal operating conditions are indicators of normal performance. If there is a substantial variation from these values, it is likely that the User's vacuum system, the cryopump, or the compressor unit is malfunctioning.

During normal operation, the operating log should be filled out at least once a day.

During the first 100 hours of operation, a slight drop in the oil level of the compressor pump may occur. Such a drop should cause no concern, as long as the oil level is visible. However, if the oil level continues to drop, to the extent that it is no longer visible, contact the Product Service Department of CTI-CRYOGENICS.

3.5 SHUTDOWN

(1) Close the Hi-Vac valve between the cryopump and the User's vacuum chamber.

(2) Switch OFF the cold-head "ON-OFF" switch (2, Figure 1-4).

(3) Switch OFF the compressor-unit "ON-OFF" switch (1).

CAUTIONS: (1) IF IT IS NECESSARY TO EXPOSE THE USER'S VACUUM CHAMBER TO ATMOSPHERIC PRESSURE, EITHER SHUT THE HI-VAC VALVE TO ISOLATE THE CRYOPUMP FROM THE USER'S VACUUM CHAMBER OR BACKFILL THE CRYOPUMP THROUGH THE ACCESSORY PORT (29, FIGURE 1-2) WITH DRY GAS, SUCH AS NITROGEN OR ARGON.

(2) DO NOT EXPOSE THE COLD INTERNAL PARTS OF THE CRYOPUMP TO THE ATMOSPHERE AFTER IT HAS BEEN SHUT DOWN. ALWAYS ALLOW TIME FOR THEM TO WARM UP TO ROOM TEMPERATURE BEFORE EXPOSURE. THIS IS TO MINIMIZE THE AMOUNT OF WATER VAPOR THAT IS ADSORBED INTO THE CHARCOAL OF THE 15K INNER CHARCOAL CHAMBER (3, FIGURE 1-2).

Note: It will take several hours to warm up the cold-head cylinder to ambient temperature with no heat load present. If a rapid warm-up is desired, break the vacuum in the User's vacuum chamber with a small amount of clean, dry gas, such as nitrogen or argon. Do not use helium to break the vacuum because of the difficulty in removing it later.

3.6 STORAGE

During storage of the CRYO-TORR(R) 8 High-Vacuum Pump while the cryopump is attached to the User's vacuum system, the vacuum housing should either be (a) maintained under vacuum or (b) kept at atmospheric pressure with dry nitrogen or argon.

The remainder of the CRYO-TORR 8 High-Vacuum Pump will be fully protected in storage if it is kept under positive helium pressure. Best results will be obtained if all components are left completely connected. The helium-supply pressure gauge on the rear panel of the compressor unit should be checked periodically to ensure that a charge pressure of 250 +0, -5 psig is being maintained.

If the cryopump is removed from the User's vacuum system, install the protective cover (11, Figure 1-2) on the mounting flange (13) at the inlet of the vacuum housing (17). Then evacuate the cryopump through the accessory port (29) and/or backfill it with a dry gas, such as nitrogen or argon.

CHAPTER 4
REGENERATION

4.1 GENERAL

All cryopumps operate by the condensation and adsorption of gases upon cold surfaces. Frost then forms upon these cold surfaces. Eventually, it becomes so thick that the cryopump must be regenerated. That is, the cold internal parts of the cryopump must be warmed to room temperature and the liberated gases must be removed.

The need for regeneration is evident when the cryopump is incapable of maintaining a high vacuum even though the cold head and the compressor unit are operating satisfactorily. Typically, an increase in the blank-off pressure by a factor greater than 100 may be taken as an indication that the cryopump needs regeneration. (The blank-off pressure of a cryopump is the lowest pressure that can be maintained in the vacuum housing of the cryopump when the Hi-Vac valve is closed; see Section 2.4.)

The need for regeneration may also be revealed by a hydrogen-vapor-pressure-gauge reading above 15 psia or, when the cryopump is equipped with the optional silicon-diode temperature sensor, by an indicated temperature that is greater than 20K. Such a high reading may be caused by a number of conditions, including (1) overloading of the cryopump by an excessive gas burst from the User's vacuum chamber at crossover, (2) the presence of a high partial pressure of noncondensibles (helium, hydrogen, and neon) within the cryopump, due to exceeding the adsorptive capacity of the charcoal in the 15K inner charcoal chamber of the cryopump, and (3) an excessive thermal load due to build-up of H_2O ice on the 80K condensing array.

Some Users prefer to perform regeneration at routine intervals, rather than waiting for obvious need to become evident. A suitable time interval must be determined by experience. It will depend upon the gas load that is being pumped and the pressure in the User's vacuum chamber.

WARNING: IF TOXIC, CORROSIVE, OR FLAMMABLE GASES ARE BEING PUMPED, CONNECT A VENT PIPE TO THE FLANGE ON THE RELIEF VALVE ASSEMBLY (18, FIGURE 1-2) AND VENT THESE GASES TO A SAFE LOCATION.

CAUTION: CARE MUST BE TAKEN IN MAKING THIS CONNECTION. A SUITABLE ADAPTER CAN BE FABRICATED BY USING VIEW B-B OF CTI-CRYOGENICS DRAWINGS E8033036 AND E8033047 (SEE APPENDIX G). THE 1.30-INCH-DIAMETER X 1.38-INCH-LONG VOLUME AROUND THE RELIEF VALVE MUST REMAIN CLEAR.

Note: CTI-CRYOGENICS Regeneration Control Unit (CTI-CRYOGENICS part number E8044001) can be used to automatically sequence the events in the various regeneration procedures.

4.2 UNASSISTED REGENERATION

(1) Shut down the CRYO-TORR(R) 8 High-Vacuum Pump in accordance with Section 3.5.

(2) Allow the cryopump arrays to warm up to ambient temperature; that is, until the hydrogen-vapor-pressure gauge indicates 80 psia or, if the cryopump is equipped with the optional silicon-diode temperature sensor, until the indicated temperature is greater than 290K. (The required warm-up time is from two to six hours.)

> *CAUTION: DO NOT ROUGH-PUMP THE CRYOPUMP UNTIL IT HAS WARMED UP TO AMBIENT TEMPERATURE. IT IS DIFFICULT TO REMOVE WATER FROM CHARCOAL AT LOWER-THAN-AMBIENT TEMPERATURES. (WHEN THE CRYOPUMP IS EQUIPPED WITH THE OPTIONAL SILICON-DIODE TEMPERATURE SENSOR, DO NOT ROUGH-PUMP THE CRYOPUMP IF THE INDICATED TEMPERATURE IS LESS THAN 290K.)*

(3) After the cryopump arrays are at ambient temperature, rough-pump the cryopump down to 50 millitorr, using the procedure of Section 3.2.

(4) Restart the high-vacuum pump in accordance with Section 3.3.

4.3 RAPID REGENERATION

The unassisted-regeneration process described in Section 4.2 can be accelerated by forced warming of the cryopump. Such rapid regeneration may be accomplished by any one of the five following procedures.

> *CAUTION: DO NOT HEAT THE CRYOPUMP ABOVE 150°F (66°C) WHEN USING THESE PROCEDURES. TO DO SO WILL RESULT IN DAMAGE TO SOME MATERIALS IN THE CRYOPUMP.*

Procedure No. 1: Backfilling the cryopump with a dry gas

> Note: The use of this backfilling procedure will shorten by 10 to 20 percent the regeneration time that is required with the unassisted-regeneration procedure of Section 4.2.

(a) Close the Hi-Vac valve if the User's vacuum system is so equipped.

(b) Shut down the CRYO-TORR(R) 8 High-Vacuum Pump in accordance with Section 3.5.

(c) Break the vacuum in the cryopump vacuum chamber with dry nitrogen or argon gas, applied through the accessory port (29, Figure 1-2).

> *CAUTION: NEVER USE HELIUM GAS TO BREAK THE VACUUM. HELIUM IS THE MOST DIFFICULT GAS TO CRYOPUMP AND EXCESSIVE QUANTITIES OF HELIUM REMAINING IN THE CRYOPUMP AFTER REGENERATION MAY IMPEDE OR LIMIT THE USEFUL OPERATION OF THE CRYOPUMP. EXCESSIVE QUANTITIES OF HELIUM WILL ALSO SHORTEN THE TIME BETWEEN SUBSEQUENT REGENERATIONS.*

(d) Allow the crypoump arrays to warm up to ambient temperature; that is, until the hydrogen-vapor-pressure gauge indicates 80 psia or, if the cryopump is equipped with the optional silicon-diode temperature sensor, until the indicated temperature is greater than 290K.

CAUTION: DO NOT ROUGH-PUMP THE CRYOPUMP UNTIL IT HAS WARMED UP TO AMBIENT TEMPERATURE. IT IS DIFFICULT TO REMOVE WATER FROM CHARCOAL AT LOWER-THAN-AMBIENT TEMPERATURES. (WHEN THE CRYOPUMP IS EQUIPPED WITH THE OPTIONAL SILICON-DIODE TEMPERATURE SENSOR, DO NOT ROUGH-PUMP THE CRYOPUMP IF THE INDICATED TEMPERATURE IS LESS THAN 290K.)

(e) Rough-pump the cryopump in accordance with Section 3.2.

(f) Restart the high-vacuum pump in accordance with Section 3.3.

Procedure No. 2: Room-temperature purging of the cryopump

Note: The use of this room-temperature purging procedure will shorten by 20 to 30 percent the regeneration time that is required with the unassisted-regeneration procedure of Section 4.2.

(a) Close the Hi-Vac valve if the User's vacuum system is so equipped.

(b) Shut down the CRYO-TORR(R) 8 High-Vacuum Pump in accordance with Section 3.5.

(c) Start a dry-gas purge (using nitrogen or argon) of the cryopump through the accessory port (29, Figure 1-2) with a flow rate of 1 to 2 cfm.

(d) Continue the purging until the hydrogen-vapor-pressure gauge indicates 80 psia or, if the cryopump is equipped with the optional silicon-diode temperature sensor, until the indicated temperature is greater than 290K.

(e) Rough-pump the cryopump in accordance with Section 3.2.

(f) Restart the high-vacuum pump in accordance with Section 3.3.

Procedure No. 3: Hot-gas purging of the cryopump

WARNING: DO NOT USE AN OPEN HOT-FILAMENT HEATER THAT IS EXPOSED TO THE PURGE-GAS STREAM. IT COULD BE A SOURCE OF IGNITION FOR FLAMMABLE GASES.

Note: The use of the following hot-gas purging procedure will accelerate the regeneration process obtained with Procedure No. 2.

(a) Close the Hi-Vac valve if the User's vacuum system is so equipped.

(b) Shut down the CRYO-TORR(R) 8 High-Vacuum Pump in accordance with Section 3.5.

(c) Start a dry-gas purge (using nitrogen or argon that has been preheated to no more than 150°F (66°C)) of the cryopump through the accessory port (29, Figure 1-2) with a flow rate of 1 to 2 cfm.

CAUTION: DO NOT HEAT THE CRYOPUMP ABOVE 150°F (66°C).

(d) Continue the purging until the hydrogen-vapor-pressure gauge indicates 80 psia or, if the cryopump is equipped with the optional silicon-diode temperature sensor, until the indicated temperature is greater than 290K.

(e) Rough-pump the cryopump in accordance with Section 3.2.

(f) Restart the high-vacuum pump in accordance with Section 3.3.

Procedure No. 4: Heating the cryopump

(a) Close the Hi-Vac valve if the User's vacuum system is so equipped.

(b) Shut down the CRYO-TORR(R) 8 High-Vacuum Pump in accordance with Section 3.5 and break the vacuum within the cryopump with a suitable dry gas (see step c of Procedure No. 1).

(c) Wrap the exterior of the vacuum housing (17, Figure 1-2) with a heating mantle or heating tape, and maintain the surface of the cryopump at a temperature up to 150°F (66°C).

CAUTION: DO NOT HEAT THE CRYOPUMP ABOVE 150°F (66°C).

(d) Allow the cryopump arrays to warm up to ambient temperature; that is, until the hydrogen-vapor-pressure gauge indicates 80 psia or, if the cryopump is equipped with the optional silicon-diode temperature sensor, until the indicated temperature is greater than 290K.

(e) Rough-pump the cryopump in accordance with Section 3.2.

(f) Restart the high-vacuum pump in accordance with Section 3.3.

Procedure No. 5: Using both heating and purging

WARNING: DO NOT USE AN OPEN HOT-FILAMENT HEATER THAT IS EXPOSED TO THE PURGE-GAS STREAM. IT COULD BE A SOURCE OF IGNITION FOR FLAMMABLE GASES.

(a) Close the Hi-Vac valve if the User's vacuum system is so equipped.

(b) Shut down the CRYO-TORR(R) 8 High-Vacuum Pump in accordance with Section 3.5.

(c) Wrap the exterior of the vacuum housing (17, Figure 1-2) with a heating mantle or heating tape, and maintain the surface temperature of the cryopump at a temperature up to 150°F (66°C).

CAUTION: DO NOT HEAT THE CRYOPUMP ABOVE 150°F (66°C).

(d) Start a dry-gas purge (using nitrogen or argon) of the cryopump through the accessory port (29, Figure 1-2) with a flow rate of 1 to 2 cfm.

(e) Continue the heating and purging until the hydrogen-vapor-pressure gauge indicates 80 psia or, if the cryopump is equipped with the optional silicon-diode temperature sensor, until the indicated temperature is greater than 290K.

(f) Rough-pump the cryopump in accordance with Section 3.2.

(g) Restart the high-vacuum pump in accordance with Section 3.3.

CHAPTER 5

TROUBLESHOOTING

5.1 TROUBLESHOOTING THE CRYOPUMP

The primary indication of trouble in a vacuum pumping system is a rise in the pressure of the User's vacuum chamber (called the base pressure). A rise in the base pressure may be caused by either a leak in the User's vacuum system or an improperly functioning cryopump. If the base pressure becomes high enough to indicate trouble, first determine if there is a leak in the User's vacuum system. If there is none, the trouble is with the cryopump.

A log of the readings of the hydrogen-vapor-pressure gauge during normal operation is a valuable tool in troubleshooting the cryopump. Values higher than 15 psia indicate that the second-stage cold station is warmer than 20K, and that the cryopump's ability to pump hydrogen is therefore impaired.

The cryopump troubleshooting procedures are summarized in Table 5-1.

5.2 TROUBLESHOOTING THE COMPRESSOR UNIT

The compressor-unit troubleshooting procedures are summarized in Table 5-2.

TABLE 5-1. CRYOPUMP TROUBLESHOOTING CHART

FAULT	POSSIBLE CAUSE	CORRECTIVE ACTION
#1 High base pressure, with hydrogen vapor pressure more than 15 psia.	1) The hydrogen capacity of the inner charcoal chamber has been exceeded.	Regenerate the cryopump to expel the condensed gases. Recool the cryopump and check its operation. Compare the cooldown parameters (cooldown time to operating temperature and the time required to achieve the desired operating vacuum of the cryopump; see Section 3.3) with those obtained previously (see operating log). If these are not essentially similar, the cold head is probably at fault.
	2) Gas conduction in the system has exceeded the gas-condensing capacity of the 15K array, and frost build-up has caused the equilibrium vacuum pressure to be higher than 1×10^{-4} torr.	
	3) The cryopump has been overloaded by an excessive gas burst at crossover.	
	4) Cold-head performance has degraded because of mechanical failure.	Check the supply pressure gauge on the compressor unit. The normal operating supply pressure should be 270-290 psig. If the reading is below this range, add gas (see Section 6.3). Regenerate and recool the cryopump. If the hydrogen vapor pressure remains high, the trouble may lie within the cold head itself. Also, check the compressor unit for normal operation (see Section 3.4).

TABLE 5-1. CRYOPUMP TROUBLESHOOTING CHART (cont.)

FAULT	POSSIBLE CAUSE	CORRECTIVE ACTION
#2 High base pressure, with hydrogen vapor pressure 15 psia or lower.	1) Frost build-up. The condensation capacity of the cryopump has been exceeded. The temperature gradient through the condensed layer has caused the base pressure to rise to the level of the vapor pressure of the condensed gas.	Regenerate the cryopump as described in Chapter 4.
	2) One of the arrays has become loose and does not make good thermal contact with its cold station on the cold head. This is an unlikely situation and should be the last suspected cause of poor vacuum performance.	Warm the cryopump to ambient temperature, and remove it from the User's vacuum system. Inspect the arrays and retighten them as necessary.
#3 The cryopump fails to cool down to the required operating temperature, or takes too long to reach that temperature.	1) Low system charge pressure in the compressor unit.	Add gas in accordance with Section 6.3.
	2) The cryopump has an excessive heat load.	Eliminate the cause of the excessive heat load and regenerate the cryopump.
	3) The cryopump is contaminated.	Purge and regenerate the cryopump, as outlined in Section 4.3.
	4) Internal compressor-unit problem.	See Table 5-2.

TABLE 5-2. COMPRESSOR-UNIT TROUBLESHOOTING CHART

WARNING: DISCONNECT THE POWER BEFORE MAKING ANY CONTINUITY CHECKS.

FAULT	POSSIBLE CAUSE	CORRECTIVE ACTION
#1 The compressor unit fails to start when power is applied.	1) No power at the User's power source.	Check the service fuses, circuit breakers, and wiring associated with the User's power source and fix as required.
	2) Incorrect or disconnected wiring within the compressor unit.	Check the compressor-unit wiring (see Figure B-1 in Appendix B).
	3) The overload protective switch (TS2) is open. (In this case, the cooling fan will run but the compressor pump will not.)	If the contact points of this switch are open when excess current is not being drawn, the switch is defective. Use the schematic of Figure B-1 and an ohmmeter to check whether the switch is open or closed. (When switch TS2 opens because of excessive current draw, the cause must be ascertained; see Possible Cause 1 for Fault No. 2.)
	4) The thermal protective switch (TS1) or the safety interlock switch (SW2) is closed.	Allow the compressor unit to cool, and then remove the compressor-unit cover. Test switches TS1 and SW2 as follows. Depress the plunger on the interlock switch (located on the side of the heat exchanger). Both switches should now be open. Test either switch for continuity. If continuity is found, contact the Product Service Department of CTI-CRYOGENICS for assistance. (Note that switches TS1 and SW2 are schematically equivalent and cannot be tested separately without altering the wiring in the electrical-control chassis.)

TABLE 5-2. COMPRESSOR-UNIT TROUBLESHOOTING CHART (cont.)

FAULT	POSSIBLE CAUSE	CORRECTIVE ACTION
#2 The compressor pump stops after several minutes of operation.	1) Excessive current draw has caused the overload protective switch (TS2) to open. (In this case, the cooling fan will run even though the compressor pump can not.)	Allow the compressor unit to cool. The compressor pump should start automatically when it has cooled sufficiently. If it does so, and stops again after several minutes of operation, contact the Product Service Department of CTI-CRYOGENICS for assistance.
	2) The voltage from the User's power source is too low.	Measure the voltage being supplied to the compressor unit. If it is low (see specifications in Table 1-2), the problem is not in the compressor unit.
	3) High temperature has caused the thermal protective switch (TS1) to close.	Check the oil level in the compressor pump. The oil level should be visible in the sight glass.
	4) The ambient temperature is unusually high.	Ensure that a free flow of air is provided to the compressor unit. Check that there is a minimum clearance of 12 inches (30 cm) at the front and back of the compressor unit. Also, check that the heat-exchanger surfaces are unobstructed and clean.
	5) Mechanical seizure.	Contact the Product Service Department of CTI-CRYOGENICS to discuss the repair or disposition of the unit.

CHAPTER 6
SERVICING AND MAINTENANCE

6.1 GENERAL

The CRYO-TORR(R) 8 High-Vacuum Pump requires little maintenance. The only scheduled service procedure is the replacement of the adsorber after every 10,000 hours of operation. Unscheduled maintenance is concerned primarily with the addition of helium gas to the system, as needed.

> *WARNING: IT IS ADVISABLE TO DISCONNECT THE COMPRESSOR UNIT FROM THE SOURCE OF ELECTRICAL POWER AS WELL AS FROM THE INTERCONNECTING PIPING TO THE COLD HEAD BEFORE PERFORMING ANY INTERNAL SERVICING OPERATIONS ON THE COMPRESSOR UNIT.*

6.2 REPLACING THE ADSORBER

Replace the adsorber as follows after a maximum of 10,000 hours of operation, as indicated by the elapsed-time meter on the front panel of the compressor unit.

> *CAUTION: ALWAYS USE TWO WRENCHES WHEN DISCONNECTING OR CONNECTING A SELF-SEALING COUPLING. SEE SECTION 2.1.*

(1) Shut down the CRYO-TORR 8 High-Vacuum Pump in accordance with Section 3.5.

(2) Disconnect the input power cable (4, Figure 1-4) of the compressor unit from the electrical power source.

(3) Disconnect the helium return and supply lines from the connectors (8, 9) at the rear of the compressor unit.

(4) Remove the rear grille (10), the front grille (11), and the cover (12) by removing the 22 screws that secure these items to the compressor unit. There is no need to remove the front panel (13) or the rear panel (14), just the 4 screws that pass through each panel and screw into the cover.

(5) Remove the bolts, nuts, and washers that secure the adsorber to the base of the compressor unit (see step 1, Figure 6-1).

> Note: Retain these items for use in securing the replacement adsorber to the base of the compressor unit.

(6) Disconnect the self-sealing coupling between the internal helium supply line and the adsorber inlet (see step 2, Figure 6-1 and Figure 6-3).

(7) Remove the jam nut and lock washer that secure the adsorber-outlet self-sealing coupling half to its support plate (see step 3, Figure 6-1).

Note: Retain these items for use in securing the replacement adsorber to the support plate.

(8) Carefully slide the adsorber inward until the adsorber-outlet self-sealing coupling half clears the support plate, and then remove the adsorber (see step 3, Figure 6-1).

WARNING: DEPRESSURIZE THE ADSORBER BEFORE DISPOSING OF IT. TO ACCOMPLISH THIS, ATTACH A MATING SELF-SEALING COUPLING HALF TO THE COUPLING HALF AT THE ADSORBER OUTLET AND TIGHTEN IT SLOWLY.

(9) Install the replacement adsorber as follows.

(a) Remove the dust caps from the self-sealing coupling halves at the adsorber inlet and the adsorber outlet.

(b) Carefully lower the adsorber into its correct position in the compressor unit, so that (see Figure 6-1) the self-sealing coupling half at the adsorber outlet fits into the support plate and the slots at the bottom of the adsorber are positioned over the holes in the base of the compressor unit.

(c) Secure the adsorber to the base of the compressor unit with the bolts, nuts, and washers that were removed in step 5.

(d) Secure the adsorber-outlet self-sealing coupling half to its support plate with the jam nut and washer that were removed in step 7.

(e) Carefully connect the self-sealing coupling half at the adsorber inlet to the mating self-sealing coupling half on the internal helium supply line (see Figure 2-3).

CAUTION: WHEN CONNECTING A SELF-SEALING COUPLING, ALWAYS USE TWO WRENCHES AND CHECK THAT THE FLAT RUBBER GASKET IS IN PLACE; SEE SECTION 2.1.

(10) Replace the cover and the front and rear grilles and secure them with their screws.

Note: In some compressor units, there is a metal tab inside the cover that must depress a white safety interlock switch when the cover is installed. In such compressor units, it is very easy to install the cover backwards, with the result that the safety interlock switch does not become depressed and the compressor unit can not be started.

(11) Check that the supply pressure gauge is at 250 +0,-5 psig. If additional gas pressure is required, follow the instructions given in Section 6.3.

(12) Add 10,000 hours to the reading on the elapsed-time meter, and write this total on the decal provided with the replacement adsorber. Affix this decal to the front panel of the compressor unit, next to the elapsed-time meter.

(13) Reconnect the helium return and supply lines to the connectors (8 and 9, Figure 1-4) at the rear of the compressor unit.

(14) Reconnect the input power cable to the electrical power source.

6.3 ADDING HELIUM GAS

During normal operation, it should rarely be necessary to add gas. If the need to add gas arises frequently, it is important to check for leakage since repeated addition of gas to maintain pressure can introduce contaminants if improper methods are used; this can eventually cause the cold head to fail. Many leaks are caused by improperly tightened self-sealing coupling connections or improperly seated relief valves. If there is a leak, fix it or replace the leaking component.

To add gas, proceed as follows.

CAUTION: DO NOT USE HELIUM GAS THAT IS LESS THAN 99.999% PURE.

(1) Remove the flare cap from the helium-gas charge fitting (6, Figure 1-4) on the rear of the compressor unit.

(2) Connect a helium bottle to the gas charge fitting by loosely attaching a charging line from the helium pressure regulator on the bottle to the 1/4-inch male flare fitting installed on the helium charge valve.

Notes: (1) The use of a two-stage regulator having a delivery pressure in the range from 10 to 300 psig is recommended.

(2) After the regulator has been installed on the helium bottle but before the bottle valve has been opened, it is important that the adjusting screw on the regulator be turned clockwise until the regulator is open. Then open the valve on the bottle and immediately back off on the regulator adjusting screw until the helium stops flowing. This procedure is required in order that both the regulator and the charging line will be purged and the air trapped in the regulator will not diffuse into the bottle.

(3) Set the pressure regulator on the helium bottle to approximately 10 to 25 psig, adjusting the pressure so as to bleed helium through the charging line. Allow the gas to flow freely around the flare fitting for 30 seconds to purge the charging line of air. Then tighten the flare nut at the end of the charging line while the helium is flowing at 10 to 25 psig.

(4) Reset the regulator to 300 psig. Slowly open the helium charge valve on the rear of the compressor unit and allow the pressure to gradually rise to 250 psig if the high-vacuum pump is not in operation and is at ambient temperature. If the high-vacuum pump is in operation, on the other hand, allow the pressure to gradually rise to 285 psig.

> Note: Use the supply pressure gauge on the rear of the compressor unit to set the charge pressure -- NOT the gauge at the regulator.

(5) Tightly close the helium charge valve on the compressor unit.

(6) Shut off the pressure regulator, and remove the charging line from the male flare fitting.

(7) Reinstall the flare cap on the male flare fitting.

6.4 DECONTAMINATION PROCEDURES

The decontamination procedures given in Sections 6.4.1 and 6.4.2 are to be used for decontaminating the helium-gas circuits of the cold head and the compressor unit of the CRYO-TORR(R) 8 High-Vacuum Pump.

One of the major sources of helium contamination in CRYO-TORR high-vacuum pumps is the use of helium gas that is of insufficient purity. Helium gas of at least 99.999% purity should be used when decontaminating CRYO-TORR high-vacuum pumps. The helium gas that is typically available for helium-leak detection or welding purposes may not be of sufficient purity and therefore should NOT be used in a CRYO-TORR high-vacuum pump. Such gas may contain impurities (chiefly nitrogen, neon, and water vapor) to the extent that they will accumulate within the cold regions of the cold head and lead to a reduction in the performance of the CRYO-TORR high-vacuum pump.

Contamination of the helium-gas circuits of a CRYO-TORR high-vacuum pump will usually be indicated by sluggish or intermittent operation (ratchetting) of the cold-head drive mechanism. Such operation will be accompanied by warming of the condensing and adsorbing arrays (as revealed by an increase in the indicated operating temperature of the cold head) and may also affect the vacuum in the User's vacuum system. In severe cases of contamination, the cold-head drive mechanism will seize and fail to operate. Such a failure is caused by a large quantity of contaminants freezing in the cold head.

The decontamination procedure given in Section 6.4.1 should be used to clean up the cold head and thereby restore its performance. It is important to note that the cold-trapping of the contaminants inside the cold head that occurs during that procedure also serves to satisfactorily purify the compressor unit whenever the level of contamination within the helium-gas circuits of the CRYO-TORR high-vacuum pump is not severe.

The decontamination procedure given in Section 6.4.2 should be used to clean up the compressor unit whenever (a) maintenance has been performed on the helium-gas circuit of the compressor unit or (b) it is suspected that the compressor unit has become severely contaminated during operation of the CRYO-TORR high-vacuum pump.

> Note: Routine replacement of the compressor-unit adsorber does not contaminate the compressor unit. As shipped, each replacement adsorber is charged with helium gas and is provided with self-sealing couplings that enable installation without contamination of the helium-gas charge.

CTI-CRYOGENICS recommends that the User not employ evacuation to decontaminate either the cold head or the compressor unit (because special equipment and procedures are required).

If the User does, however, choose to evacuate either the cold head or the compressor unit, permanent damage may result to the component concerned if it is turned on while it is being evacuated by a mechanical pump. In particular, operating either the cold-head drive motor or the compressor-pump motor under a vacuum may destroy the motor (due to the low dielectric strength of helium in the 50-millitorr range). This is but one of several problems that may result from decontamination by evacuation.

6.4.1 Decontaminating the Cold Head

If for any reason, it is suspected that the helium gas in the cold head of a CRYO-TORR(R) 8 High-Vacuum Pump has become contaminated, proceed as follows to clean up the cold head.

> Note: For this procedure, the appropriate evacuation and charging adapter must be employed. Use the evacuation and charging adapter that can be ordered as CTI-CRYOGENICS part number D8032051.
>
> *CAUTIONS: (1) WHEN CONNECTING OR DISCONNECTING A SELF-SEALING COUPLING, ALWAYS USE TWO WRENCHES. THIS IS TO AVOID LOOSENING THE BODY OF THE COUPLING FROM ITS ADAPTER.*
>
> *(2) ALWAYS CHECK THAT THE FLAT RUBBER GASKET IS IN PLACE BEFORE CONNECTING A SELF-SEALING COUPLING.*
>
> *(3) IF THE COLD HEAD STARTS TO RATCHET DURING STEP 1 BELOW, PROCEED IMMEDIATELY TO STEP 2.*

(1) Cool down the CRYO-TORR high-vacuum pump and operate it for at least one hour (preferably three hours if possible).

> Note: As a result of this step, the contaminants in the helium-gas circuits of the high-vacuum pump tend to become frozen inside the cold head, and thereby become trapped inside the cold head. The longer the high-vacuum pump is operated beyond the one-hour period, the greater is the amount of contamination that becomes isolated inside the cold head.

(2) Shut down the CRYO-TORR high-vacuum pump; see Section 3.5.

(3) IMMEDIATELY disconnect the helium return and supply lines from the gas-return and gas-supply connectors at the rear of the compressor unit, but leave them attached at the cold head.

> Notes: (1) It is imperative that the interconnecting lines be disconnected IMMEDIATELY after shutdown so that contamination can not migrate back into the compressor unit.

(2) If the interconnecting lines have NOT been disconnected IMMEDIATELY after shutdown, then the high-vacuum pump should be restarted to once again cool down the cold head in accordance with step 1. Steps 2 and 3 should then be performed.

(4) Attach the evacuation and charging adapter to the disconnected ends of the helium return and supply lines.

CAUTION: IN THE FOLLOWING STEP, DO NOT REDUCE THE PRESSURE BELOW 30 PSIG. TO DO SO MAY RESULT IN THE INTRODUCTION OF ADDITIONAL CONTAMINATION INTO THE COLD HEAD.

(5) Reduce the pressure in the cold head to a level of 30 psig by using the evacuation and charging adapter.

(6) Allow 4 hours for the second stage of the cold head to warm up to room temperature.

CAUTION: THE COLD-HEAD SECOND STAGE MUST BE AT ROOM TEMPERATURE BEFORE STEP 7 IS COMMENCED. OTHERWISE, THE DECONTAMINATION PROCEDURE WILL BE INEFFECTIVE.

Note: The warm-up time can be decreased by:
(a) backfilling the vacuum housing of the cryopump to one atmosphere with dry argon or nitrogen gas, and/or
(b) wrapping a heating tape around the vacuum housing of the cryopump.

CAUTION: DO NOT HEAT THE CRYOPUMP ABOVE 150°F (66°C). TO DO SO WILL RESULT IN DAMAGE TO SOME MATERIALS IN THE CRYOPUMP.

(7) Attach a helium bottle, regulator, and charging line to the evacuation and charging adapter and purge the charging line and regulator of air.

CAUTION: DO NOT USE HELIUM GAS THAT IS LESS THAN 99.999% PURE.

Note: After the regulator has been installed on the helium bottle but before the bottle valve has been opened, it is important that the adjusting screw on the regulator be turned clockwise until the regulator is open. Then open the valve on the bottle and immediately back off on the regulator adjusting screw until the helium stops flowing. This procedure is required in order that both the regulator and the charging line will be purged and the air trapped in the regulator will not diffuse into the bottle.

(8) Perform the following sequence of steps (a) through (d):

(a) Pressurize the cold head with helium to within +0, -5 psig tolerance of 250 psig, the static charge pressure.

Note: This pressure range is valid when the cold head is at nominal room temperature (59°F to 77°F; 15°C to 25°C).

(b) Depressurize the cold head to 30 psig.

(c) Perform flushing steps (a) and (b) four more times.

(d) Pressurize the cold head to within +0, -5 psig of the 250-psig static charge pressure and run the cold-head drive motor for 10 to 30 seconds by means of the compressor-unit "ON-OFF" switch and the cold-head "ON-OFF" switch.

(9) Perform steps (b) through (d) four more times.

Note: There will be a total of 25 flushes and a total of 5 drive-motor runs.

(10) Verify that the cold head is pressurized to within +0, -5 psig of the 250-psig static charge pressure.

(11) Disconnect the evacuation and charging adapter from the ends of the helium return and supply lines.

CAUTION: CHECK THAT THE FLAT RUBBER GASKETS ARE IN PLACE BEFORE RECONNECTING THE SELF-SEALING COUPLINGS IN STEP 12 BELOW.

(12) Reconnect the helium return and supply lines to the gas-return and gas-supply connectors at the rear of the compressor unit.

(13) Restart the CRYO-TORR high-vacuum pump; see Section 3.3.

6.4.2 Decontaminating the Compressor Unit

When the level of contamination within the helium-gas circuits of the CRYO-TORR(R) 8 High-Vacuum Pump is not severe, the use of the procedure given in Section 6.4.1 will generally decontaminate the compressor unit as well as the cold head. This is because contaminants in the compressor unit will have become isolated inside the cold head during the procedure.

Use the procedure of this section to decontaminate the compressor unit when the following conditions exist.

(a) Maintenance has been performed on the helium-gas circuit of the compressor unit (for example, replacing a filter or an orifice). For this condition, commence the clean-up with step 3 below.

(b) It is suspected that the compressor unit has become severely contaminated during operation of the CRYO-TORR high-vacuum pump. For this condition, commence the clean-up with step 1.

CAUTIONS: (1) WHEN CONNECTING OR DISCONNECTING A SELF-SEALING COUPLING, ALWAYS USE TWO WRENCHES. THIS IS TO AVOID LOOSENING THE BODY OF THE COUPLING FROM ITS ADAPTER.

(2) ALWAYS CHECK THAT THE FLAT RUBBER GASKET IS IN PLACE BEFORE CONNECTING A SELF-SEALING COUPLING.

(1) Shut down the CRYO-TORR high-vacuum pump; see Section 3.5.

(2) IMMEDIATELY disconnect the helium return and supply lines from the gas-return and gas-supply connectors at the rear of the compressor unit, but leave them attached at the cold head.

Note: To clean up the cold head, which will also have become contaminated, proceed in accordance with steps 4 through 11 of the procedure given in Section 6.4.1.

(3) Perform the following sequence of steps (a) through (e) for compressor-unit decontamination.

(a) Reduce the static pressure of the compressor unit to a level of 30 psig by removing the flare cap from the helium-gas charge fitting at the rear of the compressor unit and opening the helium charge valve while observing the supply pressure gauge.

(b) Attach a helium bottle, regulator, and charging line to the male flare fitting on the helium charge valve and purge the charging line and the regulator of air.

CAUTION: DO NOT USE HELIUM GAS THAT IS LESS THAN 99.999% PURE.

Note: After the regulator has been installed on the helium bottle but before the bottle valve has been opened, it is important that the adjusting screw on the regulator be turned clockwise until the regulator is open. Then open the valve on the bottle and immediately back off on the regulator adjusting screw until helium stops flowing. This procedure is required in order that both the regulator and the charging line will be purged and the air trapped in the regulator will not diffuse into the bottle.

(c) Pressurize the compressor unit with helium to within +0, -5 psig of 250 psig, the static charge pressure.

(d) Perform flushing steps (a) through (c) four more times.

(e) With the compressor unit pressurized to within +0, -5 psig of the 250-psig static charge pressure, run the compressor unit for 1 to 2 minutes.

(4) Perform this sequence of steps (a) through (e) two more times.

Note: There will be a total of 15 flushes and a total of 3 runs of the compressor unit.

(5) Allow the compressor unit to cool to room temperature.

(6) Verify that the compressor unit is pressurized to within +0, -5 psig of the 250-psig static charge pressure.

CAUTION: CHECK THAT THE FLAT RUBBER GASKETS ARE IN PLACE BEFORE RECONNECTING THE SELF-SEALING COUPLINGS IN STEP 7 BELOW.

(7) Reconnect the helium return and supply lines to the gas-return and gas-supply connectors at the rear of the compressor unit.

(8) Restart the CRYO-TORR high-vacuum pump; see Section 3.3.

Note: As the high-vacuum pump continues to operate, any residual contamination of the compressor unit will become isolated in the cold head and can be readily removed from the cold head by using the procedure given in Section 6.4.1; see step 9 below.

(9) As soon as convenient (but preferably after 48 hours or more of operation), again carry out the procedure given in Section 6.4.1 (starting with step 2), in order to remove the above-noted residual contamination.

6.5 SERVICING THE SELF-SEALING COUPLINGS

The self-sealing couplings employed in the CRYO-TORR(R) 8 High-Vacuum Pump are Aeroquip Type 5400 couplings. The servicing of these couplings is limited to the removal and replacement of gaskets and O-rings. Figure 6-2 shows the structure of Aeroquip Type 5400 couplings.

> Note: Coupling halves, complete with poppet valves, are available from CTI-CRYOGENICS.

Proceed as follows to service a self-sealing coupling.

> Note: It is assumed in the following procedure that the coupling concerned has been properly disconnected by the use of two wrenches; see Section 2.1.

> *WARNING: DO NOT DISASSEMBLE A COUPLING HALF UNTIL THE COMPONENT TO WHICH IT IS CONNECTED HAS BEEN DEPRESSURIZED BY BLEEDING THE HELIUM CHARGE DOWN TO ATMOSPHERIC PRESSURE. USE THE EVACUATION AND CHARGING ADAPTER; SEE SECTION 6.6.*

> *CAUTION: USE TWO WRENCHES WHEN DISASSEMBLING A COUPLING HALF. ONE WRENCH IS REQUIRED TO PREVENT THE ADAPTER FROM TURNING, AND POSSIBLY BREAKING ITS CONNECTION TO THE TUBING, WHILE THE OTHER WRENCH IS BEING USED TO REMOVE THE BODY FROM THE ADAPTER.*

(1) Remove the coupling jam nut and the associated lockwasher from a coupling half if the coupling half is secured to a panel or frame.

(2) Remove the body from the adapter of the coupling half shown at the left side of Figure 6-2.

(3) Remove the gasket from the body, and the O-ring from the adapter. Discard the gasket and the O-ring.

(4) Remove the body from the adapter of the coupling half shown at the right side of Figure 6-2.

(5) Push out the bonded-sleeve-and-stem-valve assembly.

(6) Remove the O-ring from the adapter and discard it.

(7) Thoroughly clean the parts of the two coupling halves.

(8) Sparingly lubricate with vacuum grease a replacement O-ring and gasket, and install them on the coupling half shown on the left side of Figure 6-2.

(9) Lubricate with vacuum grease a replacement O-ring and install it on the coupling half shown on the right side of Figure 6-2.

(10) Using two wrenches (see the caution at the front of Section 6.5), slowly tighten the body of each coupling half to its adapter. The recommended torque values for making this connection are as follows.

1/4-inch coupling size:	15-20 foot-pounds
1/2-inch coupling size:	35-45 foot-pounds

Note: The quarter-inch coupling size is designated by Aeroquip part numbers ending in -4; the half-inch coupling size is designated by part numbers ending in -8.

(11) Decontaminate, in accordance with Section 6.4, the components to which the two coupling halves are connected.

(12) Place one drop of oil (and only one drop) on the external mating threads, and reconnect the two coupling halves. The recommended torque value for making this connection is as follows.

1/4-inch coupling size:	10 foot-pounds
1/2-inch coupling size:	35 foot-pounds

Note: Do not use vacuum grease as a lubricant on the threads.

6.6 EVACUATION AND CHARGING ADAPTER

The evacuation and charging adapter is an optional accessory that is essential as an installation and servicing tool, and is available from CTI-CRYOGENICS. It is recommended that this adapter be purchased because it is useful when installing, maintaining, and recharging components. (As noted in Section 6.4.1, the use of this adapter is required for decontaminating the cold head.) Use CTI-CRYOGENICS part number D8032051 when ordering the adapter. Consult the Product Service Department of CTI-CRYOGENICS for further information regarding its use.

6.7 HAZARDOUS MATERIALS

WARNING: IF A CRYOPUMP IS BEING USED, OR HAS BEEN USED, TO PUMP TOXIC OR DANGEROUS MATERIALS, THE USER MUST TAKE ADEQUATE STEPS TO SAFEGUARD PERSONNEL WORKING WITH THE EQUIPMENT. (THIS IS PARTICULARLY IMPORTANT SHOULD IT BECOME NECESSARY TO DISASSEMBLE THE CONDENSING ARRAYS OF THE CRYOPUMP.) IF SUCH A CRYOPUMP IS SHIPPED TO CTI-CRYOGENICS, IDENTIFY CLEARLY THAT THIS COMPONENT HAS BEEN USED WITH TOXIC OR DANGEROUS MATERIALS.

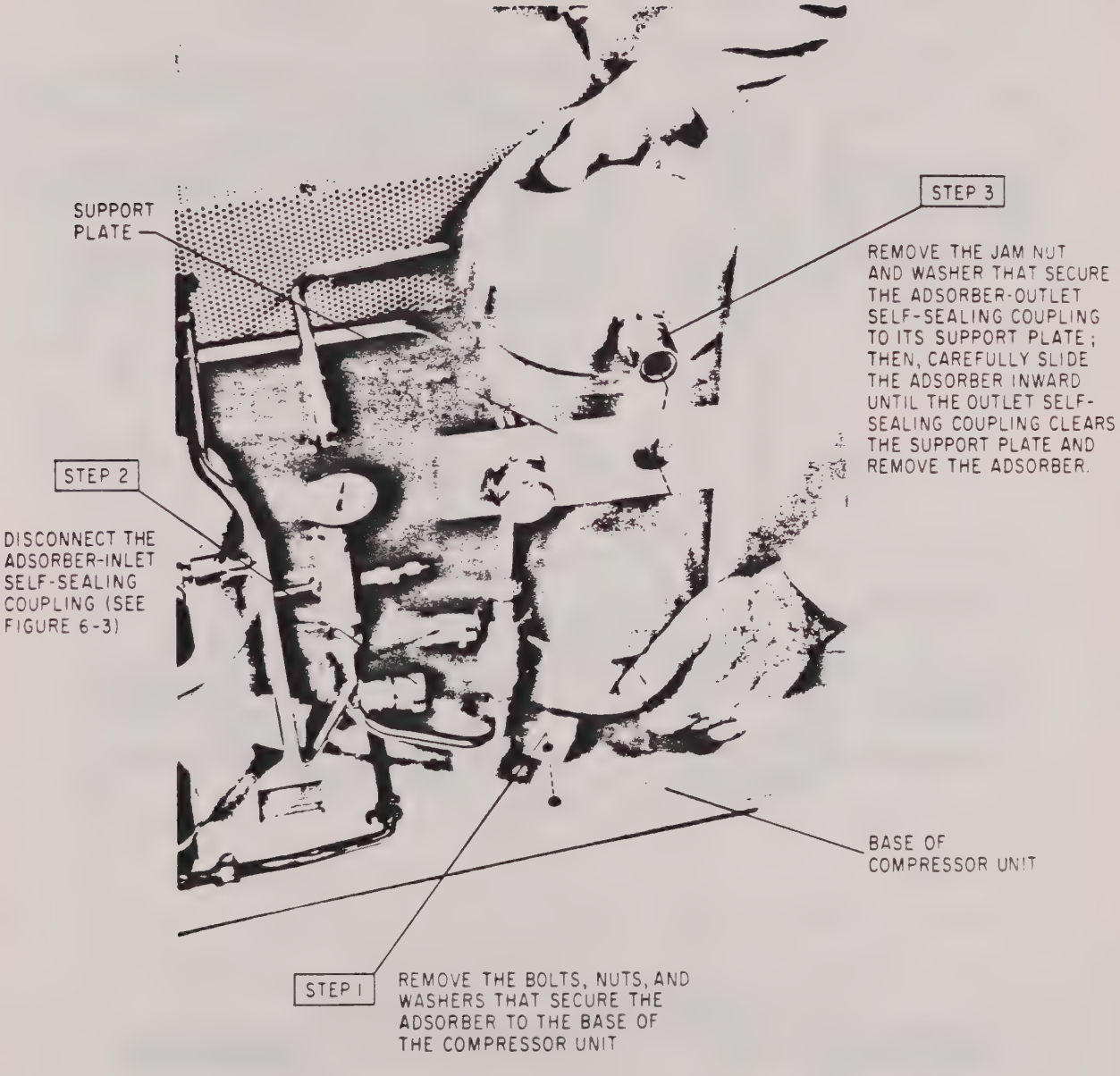

SUPPORT PLATE
STEP 3
REMOVE THE JAM NUT AND WASHER THAT SECURE THE ADSORBER-OUTLET SELF-SEALING COUPLING TO ITS SUPPORT PLATE; THEN, CAREFULLY SLIDE THE ADSORBER INWARD UNTIL THE OUTLET SELF-SEALING COUPLING CLEARS THE SUPPORT PLATE AND REMOVE THE ADSORBER.
STEP 2
DISCONNECT THE ADSORBER-INLET SELF-SEALING COUPLING (SEE FIGURE 6-3)
BASE OF COMPRESSOR UNIT
STEP 1
REMOVE THE BOLTS, NUTS, AND WASHERS THAT SECURE THE ADSORBER TO THE BASE OF THE COMPRESSOR UNIT

FIGURE 6-1. REMOVING THE ADSORBER FROM THE MODEL 350SC COMPRESSOR UNIT

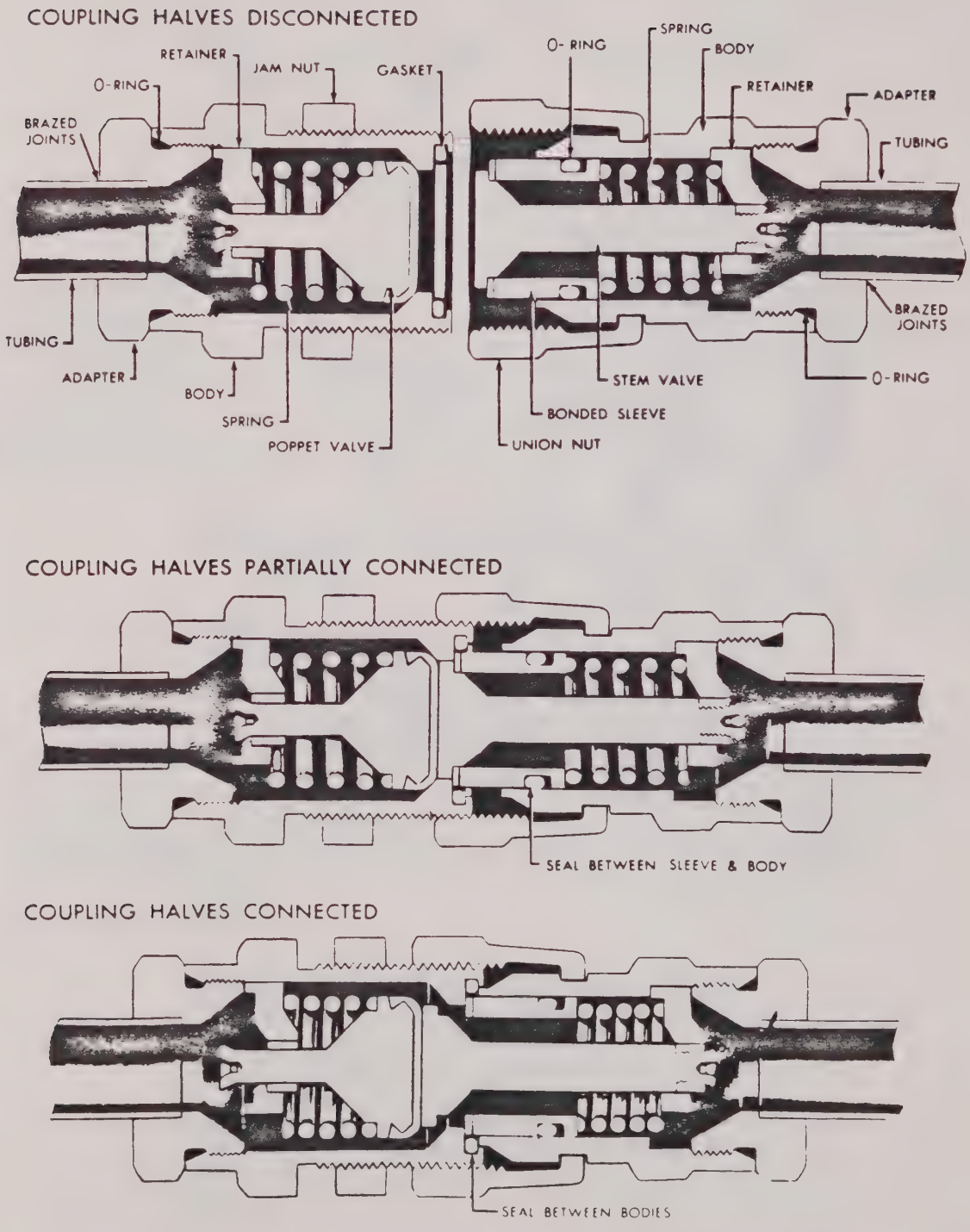


FIGURE 6-2. CUTAWAY VIEWS OF A SELF-SEALING COUPLING (AEROQUIP)

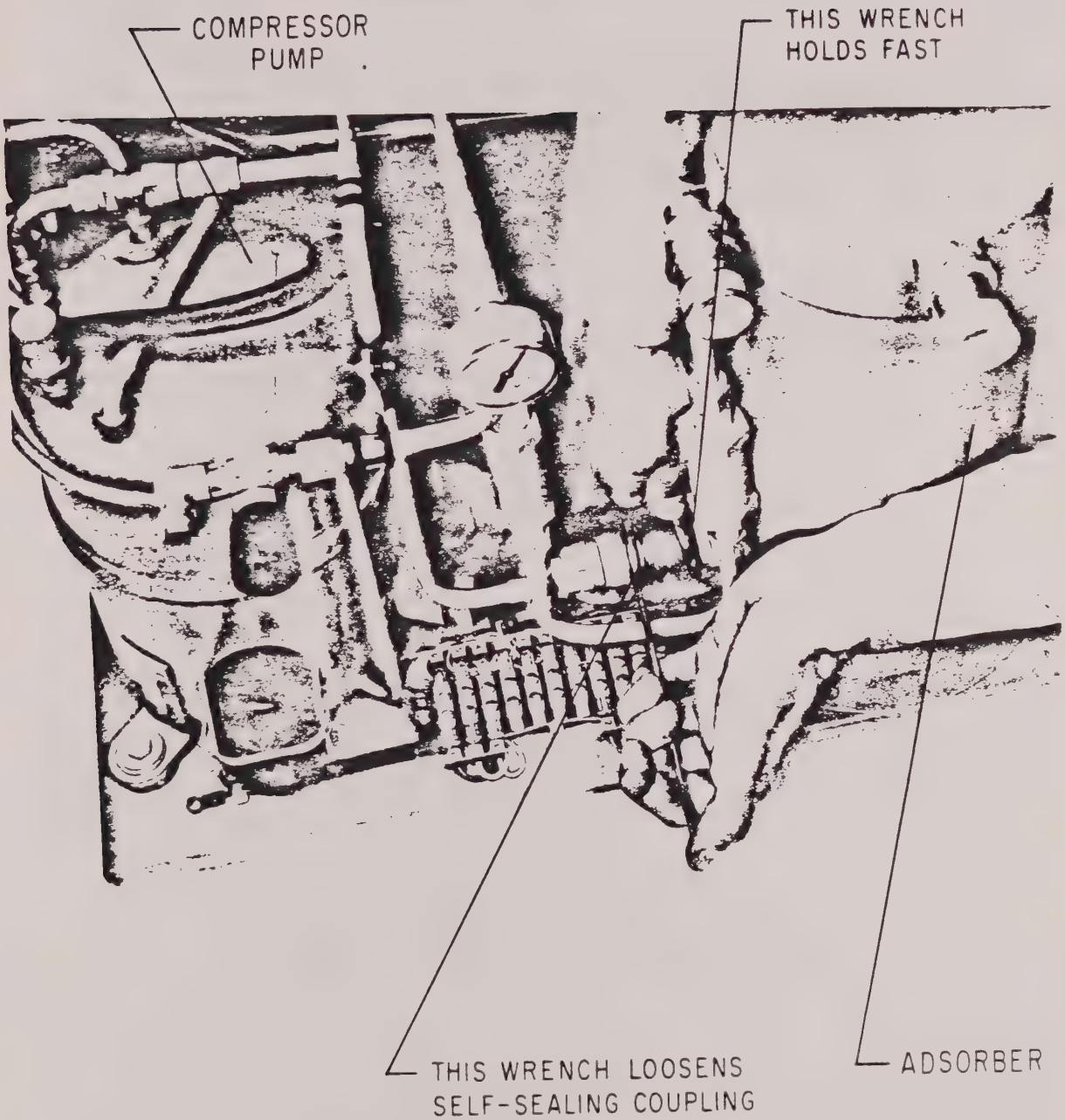


FIGURE 6-3. DISCONNECTING THE ADSORBER-INLET SELF-SEALING COUPLING IN THE MODEL 350SC COMPRESSOR UNIT

ADDENDUM FOR THE WATER-COOLED MODEL 21/350SCW COMPRESSOR UNIT

1. INTRODUCTION

This Addendum provides information relating to the water-cooled Model 21/350SCW Compressor Unit.* To use this Addendum, Users of the Model 21/350SCW Compressor Unit should first familiarize themselves with the information concerning the air-cooled Model 21/350SC Compressor Unit that is included in the basic manual for the cryogenic equipment concerned. After this is accomplished, they should refer to this supplement to look up specific information that pertains to the Model 21/350SCW Compressor Unit.

The water-cooled Model 21/350SCW Compressor Unit can be obtained in any one of the four basic configurations (depending on electrical power requirements**) that are available for the air-cooled Model 21/350SC Compressor Unit. The following tabulation shows the correspondence between the part numbers for the water-cooled Model 21/350SCW Compressor Unit and the part numbers for the air-cooled Model 21/350SC Compressor Unit.

Model 21/350SCW Compressor Unit Part Number	Corresponding Model 21/350SC Compressor Unit Part Number	
D8032096G1	D8032028G1	Model 350SC Compressor Unit
D8032096G2	D8032028G2	
D8032096G3	D8032028G3	Model 21SC Compressor Unit
D8032096G4	D8032028G4	

Other than the requirement for an external supply of cooling water, the operation (including power requirements, helium operating pressures, etc.) of the water-cooled Model 21/350SCW Compressor Unit is essentially the same as that of the air-cooled Model 21/350SC Compressor Unit. The remainder of this Addendum describes the specific ways in which the installation, operation, and servicing instructions for the Model 21/350SCW Compressor Unit differs from those for the Model 21/350SC Compressor Unit.

> Note: The specifications given in the basic manual for the cryogenic equipment concerned apply equally to the water-cooled Model 21/350SCW Compressor Unit and the air-cooled Model 21/350SC Compressor Unit.

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* The designation 21/350SCW used in this Addendum applies equally to either the Model 21SCW Compressor Unit or the Model 350SCW Compressor Unit.

** See specifications in the basic manual for the cryogenic equipment concerned.

2. INSTALLATION, OPERATION AND SERVICING INSTRUCTIONS FOR THE WATER-COOLED MODEL 21/350SCW COMPRESSOR UNIT

Figure 1 of this Addendum shows the external features of the water-cooled Model 21/350SCW Compressor Unit. Figure 2 shows the two barbed fittings (CTI-CRYOGENICS Part Number 51-97-39 and Part Number 51-40-74) that are employed to connect the external source of cooling water with the compressor unit.

All instructions and other information that pertain to the air-cooled Model 21/350SC Compressor Unit in the basic manual apply also to the water-cooled 21/350SCW Compressor Unit except as noted below.

(1) Cooling of the water-cooled Model 21/350SCW Compressor Unit is achieved by means of a counterflow tube-in-tube heat exchanger* rather than by means of an air-flow type of heat exchanger.

(2) Because the water-cooled Model 21/350SCW Compressor Unit does not utilize air flow for cooling, there is no need to provide minimum clearances of 12 inches at the front and at the back of the unit during installation.

(3) The electrical circuitry of the water-cooled Model 21/350SCW Compressor Unit differs from that of the air-cooled Model 21/350SC Compressor Unit because of the absence of a cooling fan. Accordingly, for the Model 21/350SCW Compressor Unit, refer to Figures 4 or 5, (as appropriate), of this Addendum instead of to the electrical schematic given in the basic manual.

(4) Besides the absence of a cooling fan, the water-cooled Model 21/350SCW Compressor Unit electrical circuit also employs one more thermal protective switch than the air-cooled Model 21/350SC Compressor Unit. This protective switch, which is identified as TS3 and is located on the output line of the heat exchanger (see Figure 3 of this Addendum), is normally open. The protective switch closes if the external water supply is inadequate (low flow and/or high temperature). See Figures 4 and 5 of this Addendum for the location of TS3 in the electrical circuitry of the water-cooled Model 21/350SCW Compressor Unit.

(5) Because of the electrical differences noted above, refer to the troubleshooting chart of Table 1 in this Addendum instead of the compressor-unit troubleshooting chart of the basic manual.

(6) The water-cooled Model 21/350SCW Compressor Unit has been designed to operate with water having a pH value of 6.0 to 8.0 and a calcium-carbonate concentration of less than 75 parts per million. (This is the quality of typical municipal drinking water.) When the water supplied has a pH value lower than 6.0 or a calcium-carbonate concentration in excess of 75 parts per million, contact the Product Service Department of CTI-CRYOGENICS; water conditioning may be necessary.

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* In this type of heat exchanger, the cooling water in one tube and the helium gas in the other tube flow in opposite directions.

(7) Inasmuch as the temperature of the cooling-water supply will vary occasionally and the compressor-unit cooling is dependent on both the water temperature and the flow, it is important to adjust the flow rate of the water in accordance with the temperature of the cooling-water supply as may be required to ensure adequate cooling capacity for the compressor unit. The following guidelines can be used to ensure proper compressor-unit cooling.

(a) In a majority of compressor-unit installations, adequate cooling can be provided to the compressor unit when the temperature of incoming cooling water is between 50°F and 80°F, the cooling-water flow rate is at least 1 gallon per minute at a minimum input water pressure of 5 psig and with a maximum of 100 psig.

CAUTION: THE PRESSURE OF THE COOLING WATER AS IT ENTERS THE COMPRESSOR UNIT SHOULD NOT EXCEED 100 PSIG.

(b) The compressor unit is not designed to operate with incoming cooling water temperature greater than 85°F. The incoming cooling water must be below 85°F to prevent the compressor unit from shutting down because of an over-temperature condition.

CAUTION: THE TEMPERATURE OF THE COOLING WATER AS IT LEAVES THE COMPRESSOR UNIT SHOULD NOT EXCEED 90°F.

EXAMPLE FOR DETERMINING WATER PRESSURE REQUIREMENTS (Refer to Figure 6)

After obtaining the compressor-unit water-flow-rate requirements in accordance with the procedures in Section 3.1 above, refer to the graph shown on the upper half of Figure 6 to determine the minimum cooling water supply pressure that is required for the compressor unit. In the example shown on this graph, (refer to dashed-arrows) a vertical line is drawn up from the water flow rate of 0.5 gpm until it intersected the graph curve; the minimum water supply pressure is then determined by drawing a horizontal line from this point and reading the pressure reading from the graph, which in this case is 2.5 psig.

Notes: (1) The water supply pressure as calculated in the above example is the minimum pressure required. If the water supply pressure is allowed to vary below this figure it will cause the water flow to decrease below the required 0.5 gpm rate for the example under consideration. This will cause the compressor unit to shut down because of an over-temperature condition. Therefore, for installations where the water pressure will vary, a higher water supply pressure may be required.

(2) The water supply pressure calculated in the above example does not take into consideration any discharge back-pressure conditions. In some installations, water-supply back pressure may occur because of restrictions in the User's water-return lines. Back-pressure can easily be determined by measuring the cooling-water outlet pressure. If a back-pressure condition exists, then add the back-pressure reading (psig) to the water supply pressure (previously calculated from Figure 6) to obtain the corrected minimum required water supply pressure.

3.3 DETERMINATION OF COOLING WATER TEMPERATURE RISE

Figure 7 may be used to predict the increase in the cooling-water temperature that occurs in the compressor unit, this information is used by plant engineering personnel to determine cooling-water requirements. The procedure for determining this is demonstrated in the following example.

EXAMPLE FOR DETERMINING COOLING WATER TEMPERATURE RISE (Refer to Figure 7)

Determine the compressor-unit flow rate in accordance with procedures in Section 3.1 above; then using the graph shown on Figure 7, determine the cooling-water discharge temperature rise for the compressor unit as follows:

(a) Draw a vertical line up from the minimum water flow rate determined in Section 3.1 until it intersects the graph curve (refer to the dashed-arrows in Figure 7). In this example, a vertical line is drawn from 0.5 gallon per minute to the graph curve.

(b) Draw a horizontal line at this intersecting point as shown in Figure 7 and determine the water discharge temperature increase. In the example shown in Figure 7, the predicted water discharge temperature rise is 20°F for a water flow rate of 0.5 gpm.

4. OTHER COOLING-WATER CONSIDERATIONS

(1) The cooling water must be turned off when the compressor unit is not running. Otherwise, the oil temperature will decrease causing a restriction of oil flow through the oil injection orifice during start-up. A restricted oil flow will cause the compressor unit to overheat and shut down. If this occurs, the User should turn on the compressor unit and allow it to run until it stops. Repeat this turn-on procedure a number of times until the oil temperature rises and the compressor unit is able to operate continuously for a minimum of one hour without shutting down.

(2) If the compressor unit is to be cycled on and off frequently, it is often convenient to locate a solenoid valve in the input water-supply line, this valve should also be electrically interlocked with the external power supply for the compressor unit. Contact the Product Service Department of CTI-CRYOGENICS for assistance.

(3) Before shipping a compressor unit back to CTI-CRYOGENICS, or whenever the compressor unit may be subjected to freezing conditions, always drain the water from the compressor unit and purge it of all remaining water by blowing compressed air regulated to 30-40 psig through the cooling water output connection (16, Figure 1) and allowing the compressed air to exit from the cooling-water input connection (15).

(4) Cold incoming cooling water with a temperature below the allowable operating range shown in Figure 6 should not be used with the compressor unit as this will lower the oil temperature thereby causing a restriction of oil flow through the oil-injection orifice during start up. A restricted oil flow will cause the compressor unit to overheat and shut down. Before starting the compressor unit the User should select the proper cooling-water requirements in accordance with Section 3 of this Addendum to ensure the compressor unit will have adequate cooling.

5. TROUBLESHOOTING THE MODEL 21/350SCW COMPRESSOR UNIT

Table 1 below summarizes the troubleshooting procedures for the water-cooled Model 21/350SCW Compressor Unit. Substitute this table in its entirety for the corresponding troubleshooting table in the basic manual.

TABLE 1. COMPRESSOR-UNIT TROUBLESHOOTING CHART

WARNINGS: (1) DISCONNECT THE COMPRESSOR UNIT FROM ITS POWER SOURCE BEFORE MAKING ANY CONTINUITY CHECKS.

(2) THE COMPRESSOR PUMP IS HOT AFTER THE COMPRESSOR UNIT HAS BEEN OPERATING! USE CAUTION IF IT IS NOT POSSIBLE TO WAIT FOR THE PUMP TO COOL DOWN BEFORE WORKING INSIDE THE COMPRESSOR UNIT.

Note: See Figures 4 and 5 for identification of the electrical components referenced in this table.

FAULT	PROBABLE CAUSE	CORRECTIVE ACTION
#1 The compressor-unit "ON-OFF" switch (SW1) remains in the ON position when switched on but the compressor pump will not run.	1) No power at the User's power source.	Check the service fuses, circuit breakers, and wiring associated with the User's power source and fix as required.
	2) Incorrect or disconnected wiring is present within the compressor.	Check the compressor-unit wiring (see Figures 4 and 5).
#2 The compressor-unit "ON-OFF" switch (SW1) will not remain in the ON position.	1) Either the thermal protective switches TS1 and TS3 or the safety interlock switch (SW2) is closed and, as a consequence, the relay-trip coil in the compressor-unit "ON-OFF" switch (SW1) has been activated. Note: The relay trip coil in the compressor-unit "ON-OFF" switch (SW1) can be activated by TS1, TS3 or SW2. SW1 will then automatically switch to the OFF position. See appropriate electrical schematic Figure 4 or Figure 5.	Check that the compressor-unit cover is securely in place. If this does not correct the fault, remove the compressor-unit cover and then test switches TS1, TS3 and SW2, as follows. Depress the plunger on the interlock switch (located on the side of the heat exchanger). All switches should now be open. Test any switch for continuity. If continuity is found, contact the Product Service Department of CTI-CRYOGENICS for assistance. (Note that switches TS1, TS3 and SW2 are schematically equivalent and cannot be tested separately without altering the wiring in the electrical-control chassis.)

TABLE 1. COMPRESSOR-UNIT TROUBLESHOOTING CHART (Cont.)

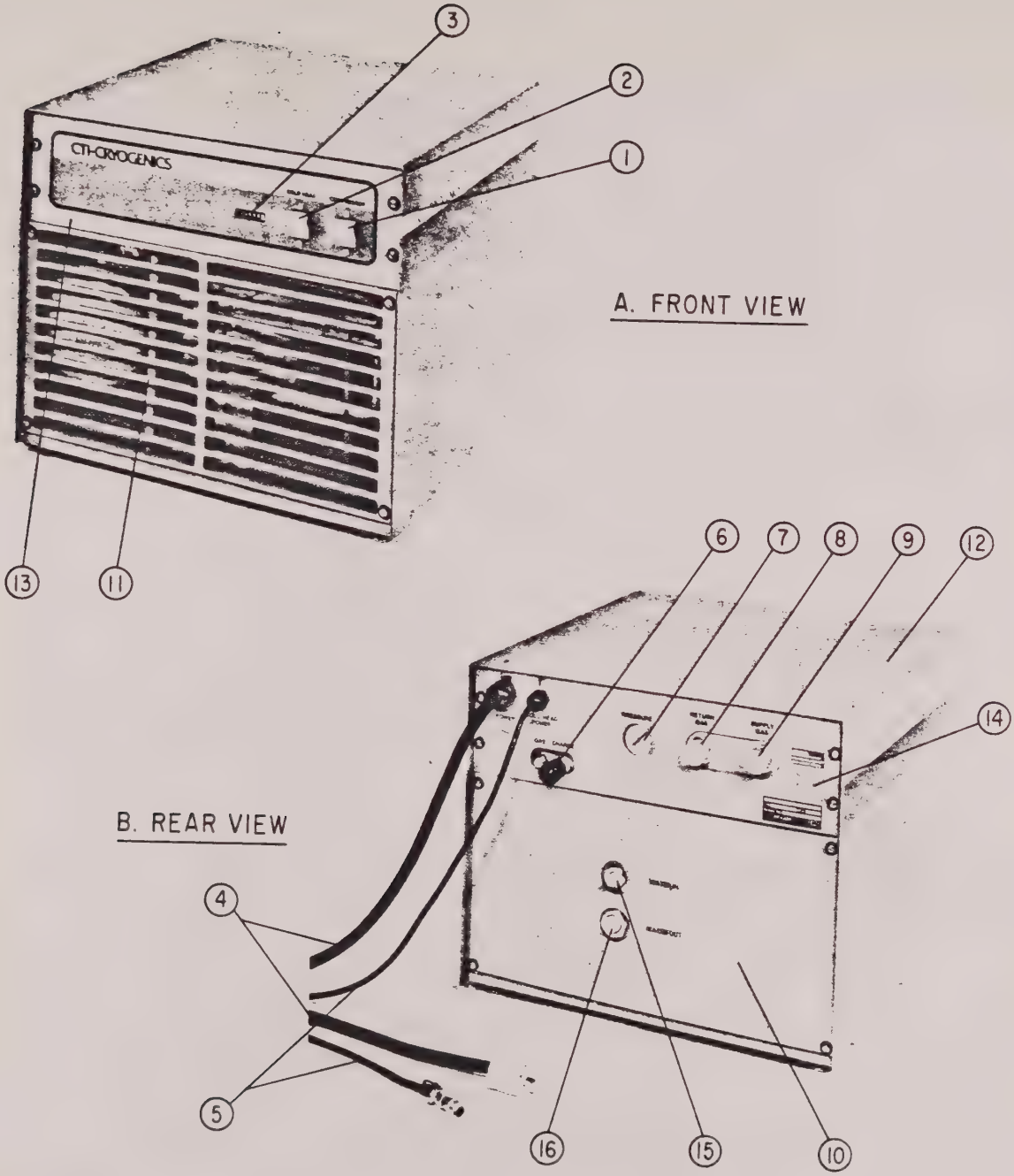
FAULT	PROBABLE CAUSE	CORRECTIVE ACTION
#2 The compressor-unit "ON-OFF" switch (SW1) will not remain in the ON position. (Cont.)	2) Either thermal protective switch TS1 or TS3 is closed.	Allow the compressor unit to cool, and then remove the compressor-unit cover. Test switch TS1 and TS3 as follows. Depress the plunger on the interlock switch (located on the side of the heat exchanger). All switches should now be open. Test each switch for continuity. If continuity is found, contact the Product Service Department of CTI-CRYOGENICS for assistance.
	3) Excessive current drain has activated the series trip in the compressor-unit "ON-OFF" switch (SW1).	Measure and record the current and contact the Product Service Department of CTI-CRYOGENICS for assistance.
#3 The compressor unit stops after several minutes of operation and remains OFF.	Excessively high temperature of the compressor unit due to inadequate cooling water has resulted in thermal protective switch TS1 or TS3 to open. See Figure 6.	Check that cooling water to the compressor unit is turned on. Check the cooling water for proper pressure and water flow rate per requirements in Section 3 and in Figure 6.

TABLE 1. COMPRESSOR-UNIT TROUBLESHOOTING CHART (Cont.)

FAULT	PROBABLE CAUSE	CORRECTIVE ACTION
#3 The compressor unit stops after several minutes of operation and remains OFF. (Cont.)	2) The cooling water was left circulating through the compressor unit after the unit was turned off, lowering the oil temperature and causing a restriction of oil flow through the metering orifice during start-up.	Turn on the compressor unit and allow it to run until it stops. Repeat this turn-on procedure a number of times until the oil temperature rises and the compressor unit is able to operate continuously for a minimum of one hour without shutting down.
	3) There is insufficient helium charge pressure.	Check the supply pressure gauge. If it reads less than as specified in the basic manual, follow the procedure given in the basic manual for adding helium.
	4) Excessively cold cooling water supply has lowered the oil temperature, causing a restriction of oil flow through the oil injection orifice during start-up.	Recheck for proper cooling-water temperature in accordance with procedures in Section 3.1.
	5) Excessively high temperature of the compressed helium in the discharge line from the compressor pump, has caused thermal protective switch TS1 to open.	Check the oil level in the compressor pump. The oil level should be visible in the sight glass.
	6) Mechanical seizure.	Contact the Product Service Department of CTI-CRYOGENICS to discuss the repair or disposition of the unit.

TABLE 1. COMPRESSOR-UNIT TROUBLESHOOTING CHART (Cont.)

FAULT	PROBABLE CAUSE	CORRECTIVE ACTION
#4 The compressor pump stops after several minutes of operation and then recycles ON and OFF at short intervals.	1) The voltage from the User's power source is too low. (Refer to voltage specification requirements in the basic manual.)	Check for too low a voltage being supplied to the compressor unit. Normal voltage must restored before the compressor unit can operate properly.
	2) Excessively high temperature of the compressor pump has caused TS2 to open and reset upon cooling down.	Measure the current and take temperature readings of the compressor pump housing (adjacent to electrical connections). Contact the Product Service Department of CTI-CRYOGENICS for assistance.



LEGEND:

1. COMPRESSOR-UNIT "ON-OFF" SWITCH
2. COLD-HEAD "ON-OFF" SWITCH
3. ELAPSED-TIME METER (ETM)
4. INPUT POWER CABLE
5. COLD-HEAD POWER CABLE
6. GAS CHARGE FITTING
7. SUPPLY PRESSURE GAUGE
8. GAS-RETURN CONNECTOR
9. GAS-SUPPLY CONNECTOR
10. REAR PLATE
11. FRONT GRILLE
12. COVER
13. FRONT PANEL
14. REAR PANEL
15. COOLING-WATER INPUT CONNECTION*
16. COOLING-WATER OUTPUT CONNECTION*

* SEE FIGURE 2 FOR THE WATER-CONNECTION BARBED FITTINGS THAT ARE EMPLOYED.

FIGURE 1. THE WATER-COOLED MODEL 21/350SCW COMPRESSOR UNIT

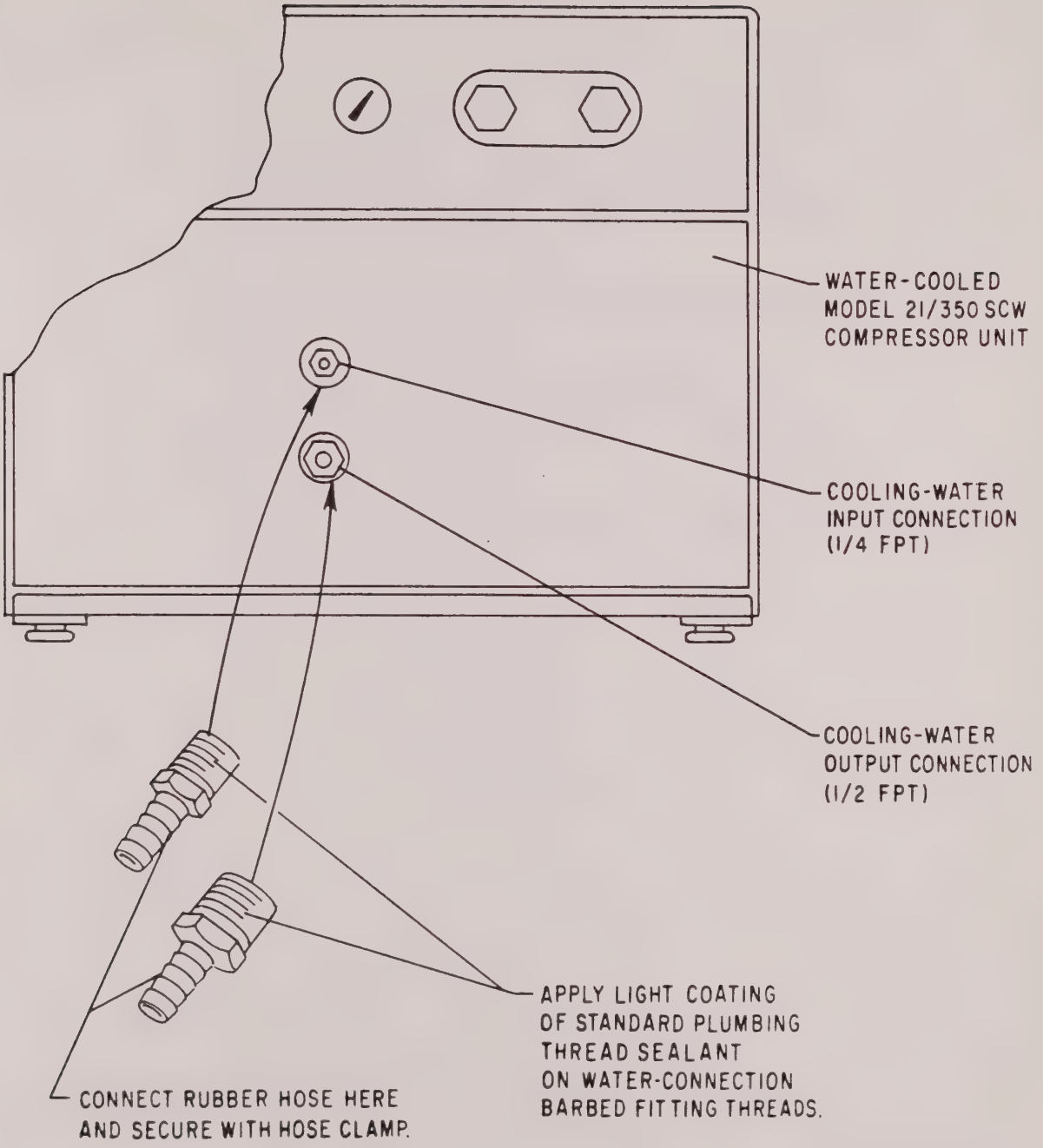


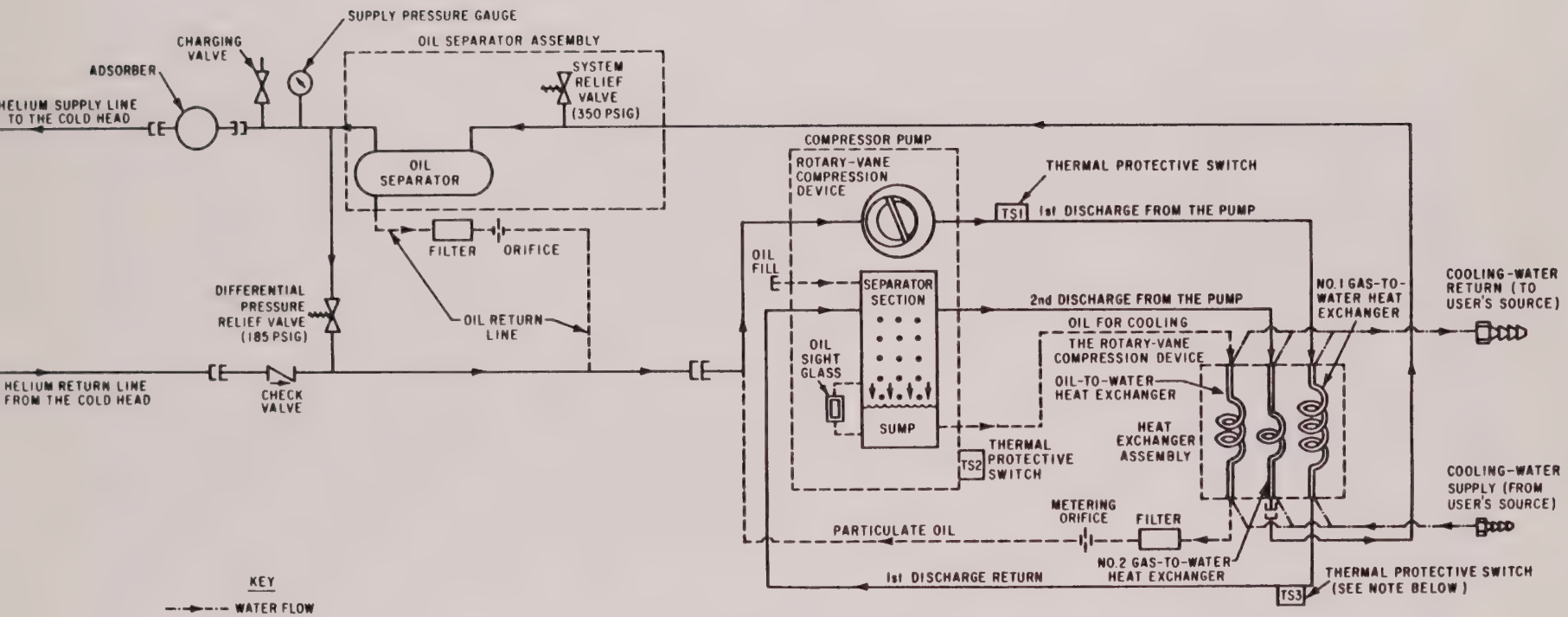
FIGURE 2. THE WATER-CONNECTION BARBED FITTINGS EMPLOYED WITH THE WATER-COOLED MODEL 21/350SCW COMPRESSOR UNIT

LIST OF ILLUSTRATIONS

FIGURE NUMBER	TITLE
1	THE WATER-COOLED MODEL 21/350SCW COMPRESSOR UNIT
2	THE WATER-CONNECTION BARBED FITTINGS EMPLOYED WITH THE WATER-COOLED MODEL 21/350SCW COMPRESSOR UNIT
3	FLOW DIAGRAM FOR THE WATER-COOLED MODEL 21/350SCW COMPRESSOR UNIT
4	ELECTRICAL SCHEMATIC FOR MODEL 350SCW COMPRESSOR UNIT PART NO. D8032096G1 OR PART NO. D8032096G2
5	ELECTRICAL SCHEMATIC FOR MODEL 21SCW COMPRESSOR UNIT PART NO. D8032096G3 OR PART NO. D8032096G4
6	WATER REQUIREMENTS DATA FOR THE WATER-COOLED MODEL 21/350SCW COMPRESSOR UNIT
7	WATER DISCHARGE TEMPERATURE DATA FOR THE WATER-COOLED MODEL 21/350SCW COMPRESSOR UNIT

LIST OF TABLES

TABLE NUMBER	TITLE
1	COMPRESSOR-UNIT TROUBLESHOOTING CHART



NOTE: THERMAL PROTECTIVE SWITCH TS3, WHICH IS PHYSICALLY LOCATED ON THE OUTPUT LINE OF THE HEAT EXCHANGER, IS NORMALLY OPEN. IT CLOSES IF THE EXTERNAL COOLING-WATER SUPPLY IS INADEQUATE. SEE FIGURES 4 AND 5 FOR THE LOCATION OF TS3 IN THE ELECTRICAL CIRCUITRY OF THE MODEL 21/350 SCW COMPRESSOR UNIT.

FIGURE 3. FLOW DIAGRAM FOR THE WATER-COOLED MODEL 21/350SCW COMPRESSOR UNIT

APPENDIX A

ILLUSTRATED PARTS BREAKDOWN FOR THE CRYO-TORR(R) 8 CRYOPUMP

An illustrated parts breakdown is included for the CRYO-TORR 8 Cryopump only (rather than for the complete CRYO-TORR 8 High-Vacuum Pump, which includes the Model 350SC Compressor Unit). This breakdown is provided for the convenience of the User in the event that disassembly beyond the scope of this manual is required (for example, if severe contamination of the cryopump arrays has occurred). Contact the Product Service Department of CTI-CRYOGENICS if further assistance is required.

LEGEND FOR FIGURE A-1

Item Number	Part Number	Description	No. Req'd
-	E8033047G01	CRYO-TORR(R) 8 Cryopump	1
1	D8033019	80K Array Assembly	1
2	------	Cap Screw, Hexagon Socket Type, SSTL, #6-32 x 1/2" Lg.	12
3	------	Lockwasher, Split Type, SSTL, #6	22
4	D8033021	15K Array Assembly	1
5	D8033020	Inner Charcoal Chamber Assembly*	1
6	------	Cap Screw, Hexagon Socket Type, SSTL, #6-32 x 3/8" Lg.	10
7	------	Washer, Flat, SSTL, #6	18
8	D8033018	80K Radiation Shield	1
9	A3543609P02	Portion of the pressure relief valve that can be taken apart for cleaning	1
10	58-64-47	O-Ring for Pressure Relief Valve	1
11	B3996034	Accessory-Port Cover	1
12	58-64-42	O-Ring, #2-20, Viton, Parker V377-9	2
13**	C8033022	Hydrogen-Vapor-Pressure Gauge Assembly	1
14	------	Cap Screw, Hexagon Socket Type, SSTL, #2-56 x 1/2" Lg.	2
15	------	Lockwasher, Split Type, SSTL, #2	2
16	D8033034	Drive Unit - Displacer Assembly	1
17	58-03-22	O-Ring, #2-140, Buna-N, Parker N219-7	1
18	------	Cap Screw, Hexagon Socket Type, SSTL, #10-32 x 1/2" Lg.	2
19	------	Cap Screw, Hexagon Socket Type, SSTL, #10-32 x 1-1/4" Lg.	4
20	C3996022	Protective Cover	1
21	58-64-41	O-Ring, #2-172, Viton, Parker V377-9	1
22	------	Screw, Hexagon Head, SSTL, 5/16-24 x 5/8" Lg.	4
23	------	Washer, Flat, SSTL, 3/8"	4
24	E8033016	Vacuum Housing	1
-	50-50-13	Indium Sheet, 3" x 6" x 0.005" thick	1

*Also known as the 15K Cryo-Adsorbing Array Assembly.

**13A	C8042003G02	Optional Diode Assembly	1

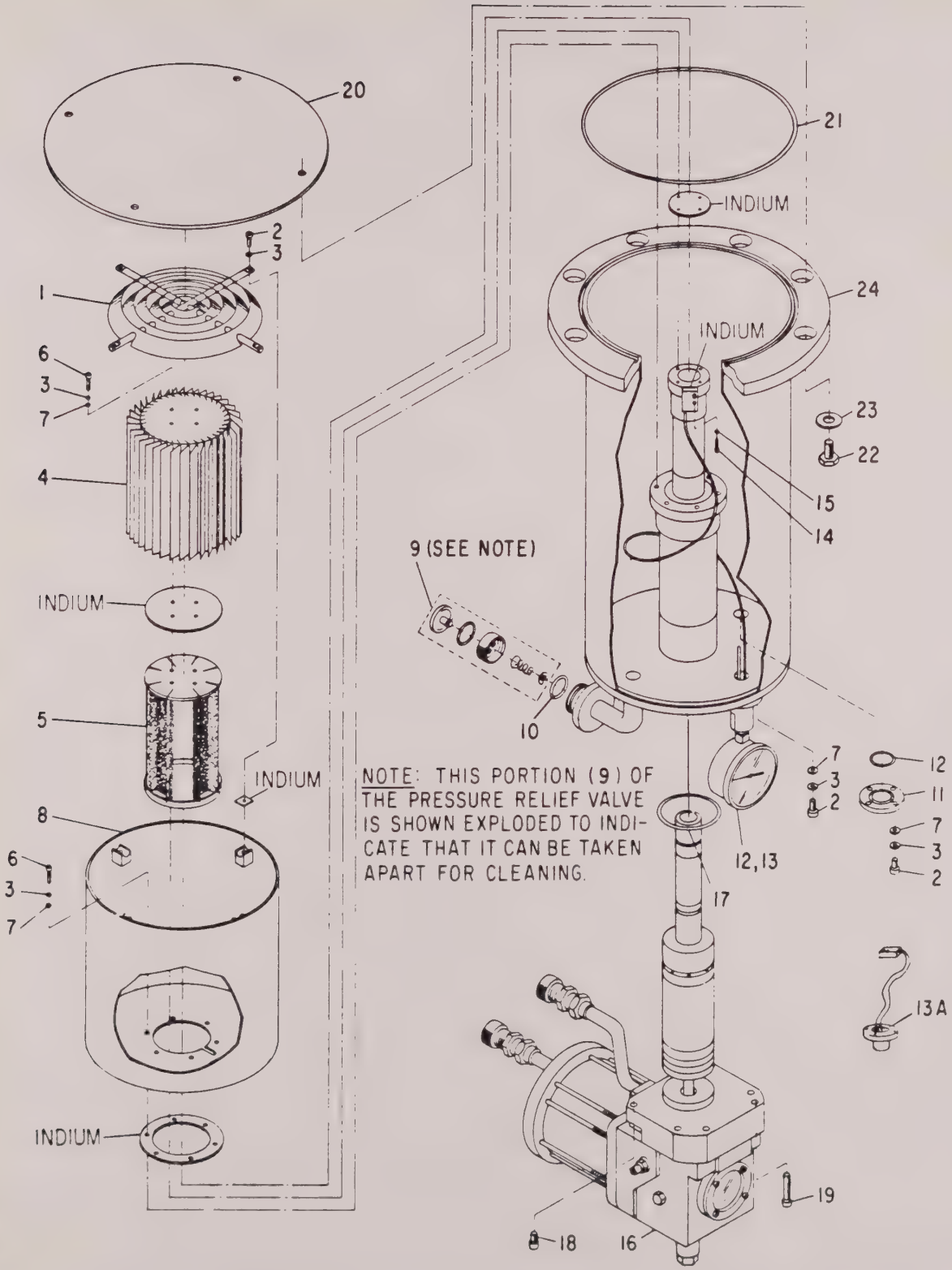
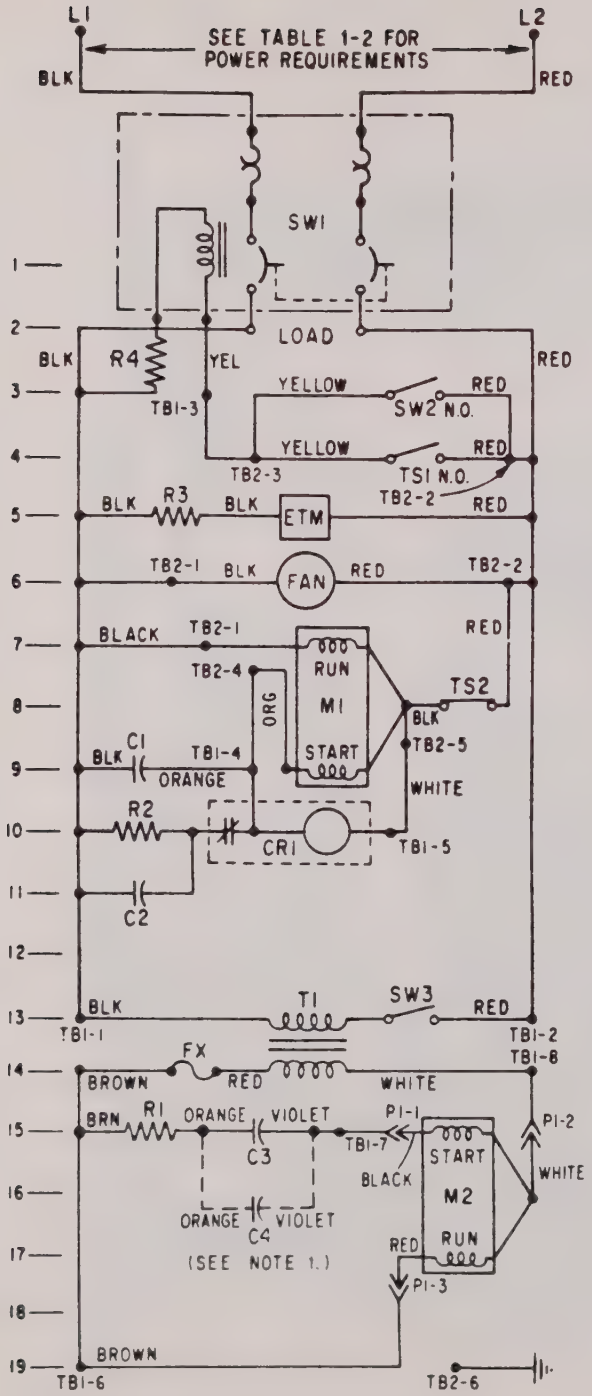


FIGURE A-1 EXPLODED VIEW OF THE CRYO-TORR® 8 CRYOPUMP

APPENDIX B

ELECTRICAL SCHEMATIC AND LOCATION INFORMATION

An electrical schematic (see Figure B-1) and an illustration showing the physical location of electrical-control-chassis components (see Figure B-2) are provided for the convenience of the User in case an electrical problem beyond the scope of this manual should occur.



LEGEND

C1 - COMPRESSOR-RUN PHASE-SHIFTING CAPACITOR - 25 μFD, 440 V
C2 - COMPRESSOR START CAPACITOR - 48 ± 5 μFD, 330 V
C3 - COLD-HEAD-DRIVE-MOTOR PHASE-SHIFTING CAPACITOR - 6 μFD, 330 V
C4 - COLD-HEAD-DRIVE-MOTOR PHASE-SHIFTING CAPACITOR - 2 μFD, 330 V (FOR 50-Hz OPERATION ONLY)
CR1 - COMPRESSOR STARTING RELAY
ETM - ELAPSED-TIME METER
FAN - COOLING FAN
FX - COLD-HEAD CIRCUIT FUSE-1 AMP
M1 - COMPRESSOR PUMP MOTOR
M2 - COLD-HEAD DRIVE MOTOR
P1 - COLD-HEAD CABLE CONNECTOR
R1 - COLD-HEAD-DRIVE-MOTOR PHASE-SHIFTING RESISTOR - 150 Ω
R2 - COMPRESSOR START RESISTOR - 18K Ω
R3 - BALLAST RESISTOR FOR ELAPSED TIME METER - 13K Ω
R4 - CURRENT-LIMITING RESISTOR - 680 Ω, 1W
SW1 - COMPRESSOR "ON-OFF" SWITCH
SW2 - SAFETY INTERLOCK SWITCH
SW3 - COLD-HEAD "ON-OFF" SWITCH
T1 - COLD-HEAD ISOLATION TRANSFORMER 140-168 V OUTPUT
TB1 - TERMINAL BOARD (CHASSIS)
TS1 - THERMAL PROTECTIVE SWITCH
TS2 - OVERCURRENT PROTECTIVE SWITCH
TB2 - TERMINAL BOARD (COMPRESSOR)

NOTES:

1. C4 IS FOR 50-Hz OPERATION ONLY.
2. TERMINAL-BOARD MECHANICAL LINKAGES ARE AS FOLLOWS:

TB1-1 ↔ TB2-1
TB1-1 ↔ TB2-1
TB1-2 ↔ TB2-2
TB1-2 ↔ TB2-2
TB2-2
TB2-3
TB2-3

FIGURE B-1. ELECTRICAL SCHEMATIC FOR THE MODEL 350SC COMPRESSOR UNIT

LEGEND - FIGURE B-2

Item Number	Description	Symbol Designation
1	1.0 Ampere Fuse	FX
2	Terminal Board No. 1	TB1
3	Compressor-Unit "ON-OFF" Switch	SW1
4	Cold-Head "ON-OFF" Switch	SW3
5	Step-down Transformer	T1
6	Elapsed Time Meter	ETM
7	13K-ohm, 2-watt Resistor	R3
8	Compressor-Unit Start Relay	CR1
9	6-microfarad Capacitor	C3
10	18K-ohm, 2-watt Resistor (see Note 2)	R2
11	25-microfarad Capacitor	C1
12	150-ohm, 50-watt Resistor	R1
13	2-microfarad Capacitor (see Note 3)	C4
14	48 ± 5 microfarad Capacitor	C2
15	680-ohm, 1-watt Resistor	R4

Notes: (1) See Figure B-1 for the location of these items in the electrical circuit for the electrical-control chassis.

(2) Resistor R2 is located on the front of capacitor C2 and is not visible in Figure B-2.

(3) Capacitor C4 is present only in a compressor unit that is designed for 50-Hz operation.

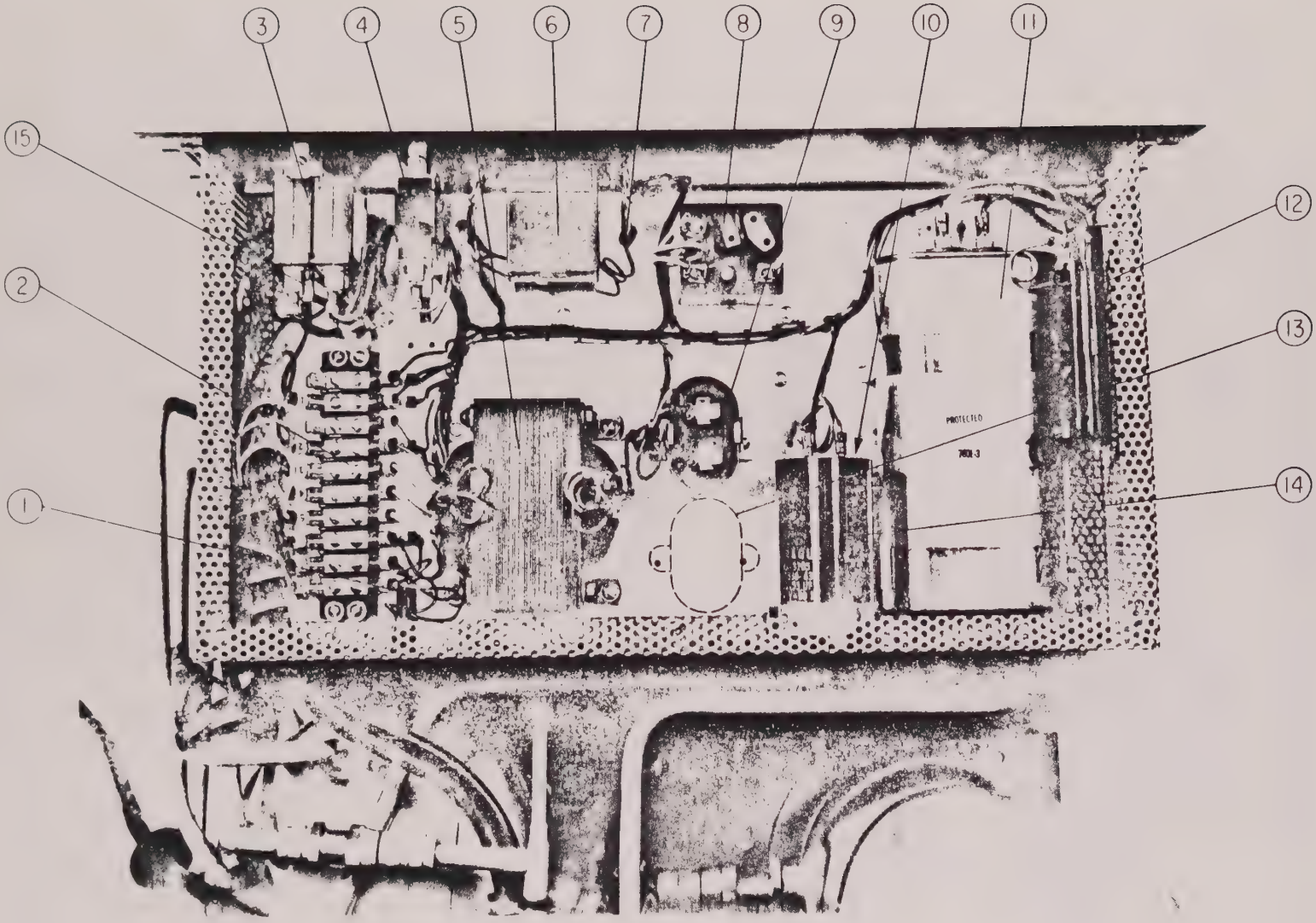


FIGURE B-2 COMPONENTS IN THE ELECTRICAL-CONTROL CHASSIS OF THE MODEL 350SC COMPRESSOR UNIT

APPENDIX C

EQUIPMENT LIST FOR THE CRYO-TORR(R) 8 HIGH-VACUUM PUMP

Item Number	Quantity	Part Number	Description
1	1	*	CRYO-TORR(R) 8 Cryopump
2	1	**	Model 350SC Compressor Unit
3	2	D3592252P20	Flexible Interconnecting Piping
4	1	8032040G04	Installation Tool Kit (see Appendix D)
5	1	58-64-41	O-Ring, #2-172, Viton, Parker V377-9
6	1	M8040003	Installation, Operation, and Servicing Instructions for the CRYO-TORR 8 High-Vacuum Pump
		* E8033047G01	CRYO-TORR(R) 8 Cryopump with hydrogen-vapor-pressure gauge
		E8033036G01	CRYO-TORR(R) 8 Cryopump with silcon-diode temperature sensor
		** D8032028G01	Model 350SC Compressor Unit (60 Hz)
		D8032028G02	Model 350SC Compressor Unit (50 Hz)

OPTIONAL ITEM

1	D8032051	Evacuation and Charging Adapter

APPENDIX D

INSTALLATION TOOL KIT (KIT NO. 8032040G4)

Item Number	Quantity	Description
1	1	1-inch open-end wrench, Armstrong, for self-sealing coupling
2	1	1 1/8-inch open-end wrench, Armstrong, for self-sealing coupling
3	1	1 3/16-inch open-end wrench, Armstrong, for self-sealing coupling
4	1	7/64-inch Hex ball-end speed wrench, Bondhus BS 7/64
5	4	Gasket seal, Aeroquip 22008-8, for self-sealing coupling
6	1	Fuse, 250 volts, 1 ampere, Buss MDL-1
7	1	Indium sheet 3" x 3" x 0.005"

APPENDIX E

PRINCIPLES OF OPERATION

The following Technical Data sheet explains the principles of operation by which the cold head and compressor unit employed in the CRYO-TORR(R) 8 High-Vacuum Pump achieve cryogenic levels of refrigeration.

APPENDIX F

CONVERSION OF HYDROGEN-VAPOR-PRESSURE-GAUGE READINGS TO TEMPERATURE

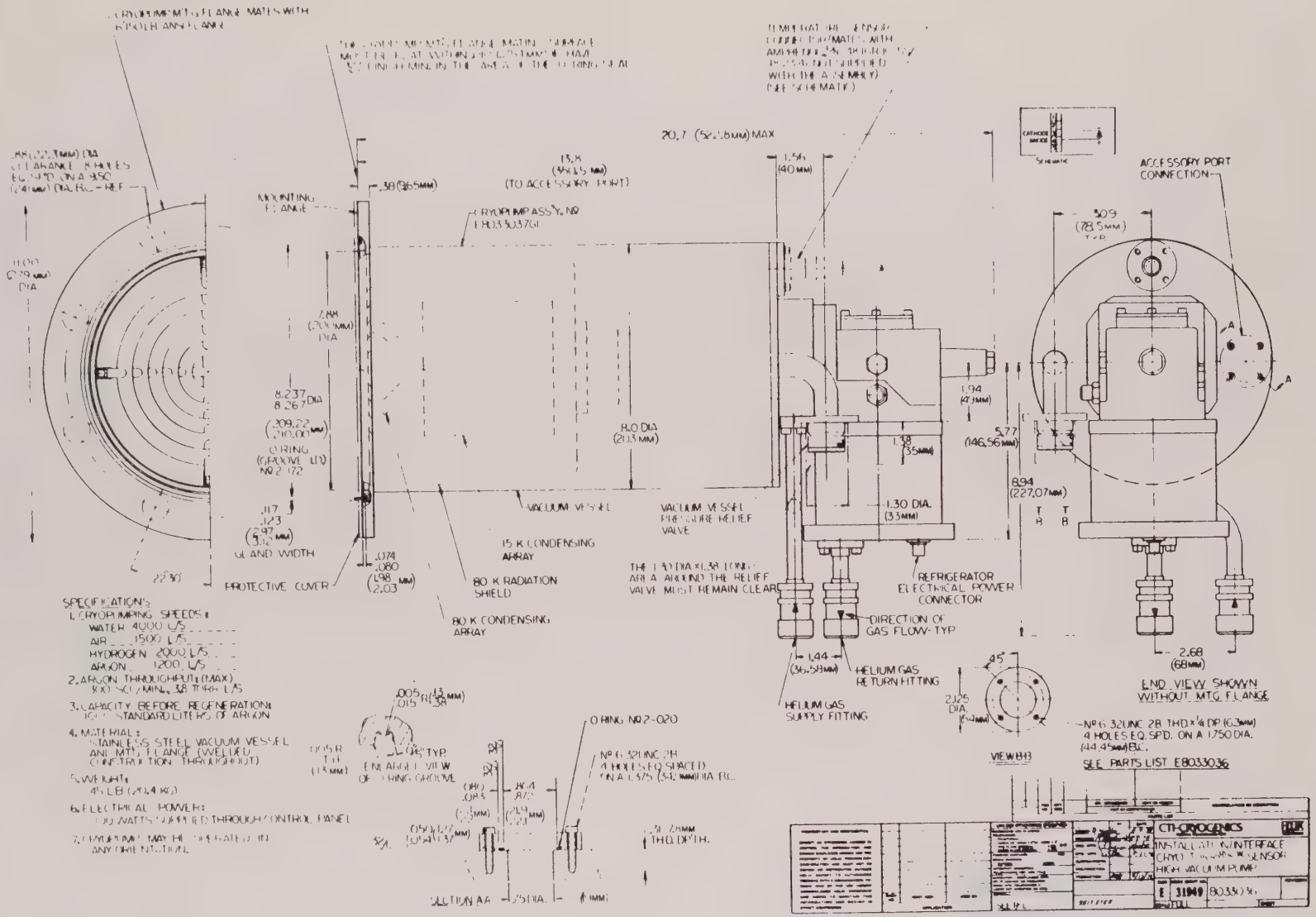
Use the data given in Table F-1 to convert a reading of the hydrogen-vapor-pressure gauge (in psia) to the temperature of the second-stage cold station (in degrees Kelvin).

TABLE F-1. TEMPERATURE VS. HYDROGEN-VAPOR-PRESSURE-GAUGE READINGS

PSIA	K	PSIA	K	PSIA	K	PSIA	K
0.2	11.76	10.0	19.15	19.8	21.44	41.0	24.40
0.4	12.60	10.2	19.21	20.0	21.47	41.5	24.46
0.6	13.15	10.4	19.27	20.2	21.51	42.0	24.51
0.8	13.56	10.6	19.33	20.4	21.55	42.5	24.57
1.0	13.89	10.8	19.39	20.6	21.58	43.0	24.62
1.2	14.20	11.0	19.45	20.8	21.62	43.5	24.67
1.4	14.48	11.2	19.50	21.0	21.65	44.0	24.73
1.6	14.73	11.4	19.56	21.2	21.69	44.5	24.78
1.8	14.96	11.6	19.61	21.4	21.72	45.0	24.83
2.0	15.17	11.8	19.67	21.6	21.76	45.5	24.88
2.2	15.36	12.0	19.72	21.8	21.79	46.0	24.93
2.4	15.54	12.2	19.77	22.0	21.83	46.5	24.98
2.6	15.71	12.4	19.83	22.5	21.91	47.0	25.03
2.8	15.87	12.6	19.88	23.0	22.00	47.5	25.08
3.0	16.02	12.8	19.93	23.5	22.08	48.0	25.13
3.2	16.17	13.0	19.98	24.0	22.16	48.5	25.18
3.4	16.31	13.2	20.03	24.5	22.24	49.0	25.23
3.6	16.44	13.4	20.08	25.0	22.32	49.5	25.28
3.8	16.56	13.6	20.13	25.5	22.40	50.0	25.33
4.0	16.69	13.8	20.18	26.0	22.47	50.5	25.37
4.2	16.80	14.0	20.22	26.5	22.55	51.0	25.42
4.4	16.92	14.2	20.27	27.0	22.62	51.5	25.47
4.6	17.03	14.4	20.32	27.5	22.70	52.0	25.52
4.8	17.13	14.6	20.36	28.0	22.77	52.5	25.56
5.0	17.23	14.8	20.41	28.5	22.84	53.0	25.61
5.2	17.33	15.0	20.46	29.0	22.91	53.5	25.65
5.4	17.43	15.2	20.50	29.5	22.98	54.0	25.70
5.6	17.52	15.4	20.55	30.0	23.05	54.5	25.75
5.8	17.62	15.6	20.59	30.5	23.12	55.0	25.79
6.0	17.71	15.8	20.63	31.0	23.19	55.5	25.83
6.2	17.79	16.0	20.68	31.5	23.26	56.0	25.88
6.4	17.88	16.2	20.72	32.0	23.32	56.5	25.92
6.6	17.96	16.4	20.76	32.5	23.39	57.0	25.97
6.8	18.04	16.6	20.80	33.0	23.45		
7.0	18.12	16.8	20.85	33.5	23.52		
7.2	18.20	17.0	20.89	34.0	23.58		
7.4	18.28	17.2	20.93	34.5	23.64		
7.6	18.35	17.4	20.97	35.0	23.70		
7.8	18.43	17.6	21.01	35.5	23.77		
8.0	18.50	17.8	21.05	36.0	23.83		
8.2	18.57	18.0	21.09	36.5	23.89		
8.4	18.64	18.2	21.13	37.0	23.95		
8.6	18.71	18.4	21.17	37.5	24.00		
8.8	18.77	18.6	21.21	38.0	24.06		
9.0	18.84	18.8	21.25	38.5	24.12		
9.2	18.90	19.0	21.28	39.0	24.18		
9.4	18.97	19.2	21.32	39.5	24.24		
9.6	19.03	19.4	21.36	40.0	24.29		
9.8	19.09	19.6	21.40	40.5	24.35		

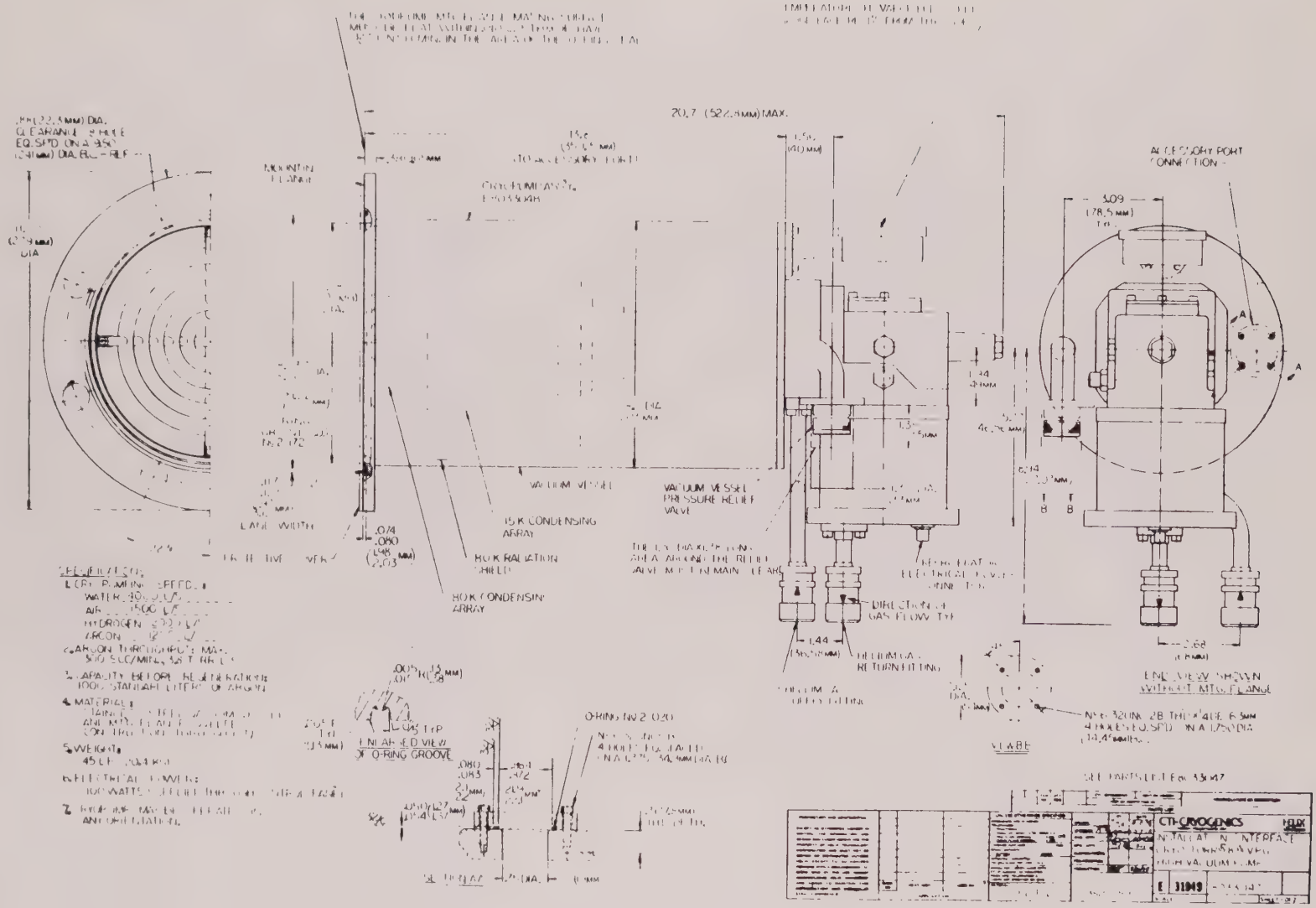
APPENDIX G

CRYOPUMP INSTALLATION/INTERFACE DRAWINGS



SPECIFICATIONS

1. CRYOPUMPING SPEEDS:
   WATER 4000 L/S
   AIR 1500 L/S
   HYDROGEN 2000 L/S
   ARGON 1200 L/S
2. ARGON THROUGHPUT: (MAX)
   800 SCC/MIN. 38 TORR L/S
3. CAPACITY BEFORE REGENERATION:
   10,000 STANDARD LITERS OF ARGON
4. MATERIAL:
   STAINLESS STEEL VACUUM VESSEL
   ANL MTG. FLANGE (WELDED CONSTRUCTION THROUGHOUT)
5. WEIGHT:
   45 LB (20.4 KG)
6. ELECTRICAL POWER:
   100 WATTS (SUPPLIED THROUGH CONTROL PANEL)
7. CRYOPUMP MAY BE OPERATED IN ANY ORIENTATION


20.7 (527.3 MM) MAX.
ACCESSORY PORT CONNECTION
3.09 (78.5 MM) TYP.
VACUUM VESSEL
VACUUM VESSEL PRESSURE RELIEF VALVE
15K CONDENSING ARRAY
RADIATION SHIELD
80K CONDENSING ARRAY
DIRECTIONAL GAS FLOW TYP
HELIUM G.A. RETURN FITTING
HELIUM G.A. SUPPLY FITTING
END VIEW SHOWN WITHOUT MTG. FLANGE
VIEW B
ENLARGED VIEW OF O-RING GROOVE
O-RING NO 2-020
CTI-CRYOGENICS
CRYOTORUS VFL
VACUUM MANIFOLD

M8040064

ADDENDUM FOR
THE
WATER-COOLED MODEL 21/350SCW
COMPRESSOR UNIT

NOVEMBER 1980

Note: This Addendum provides appropriate information for Users of CTI-CRYOGENICS equipment that incorporates the water-cooled Model 21/350SCW Compressor Unit. (These compressor units are designated as such by their nameplates.)

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CTI-CRYOGENICS
Kelvin Park, 266 Second Ave., Waltham, Mass. 02154, USA • Tel (617) 890-9400 • Telex 92-3442 • Duns 04-170-8322

HELIX
A Helix Company

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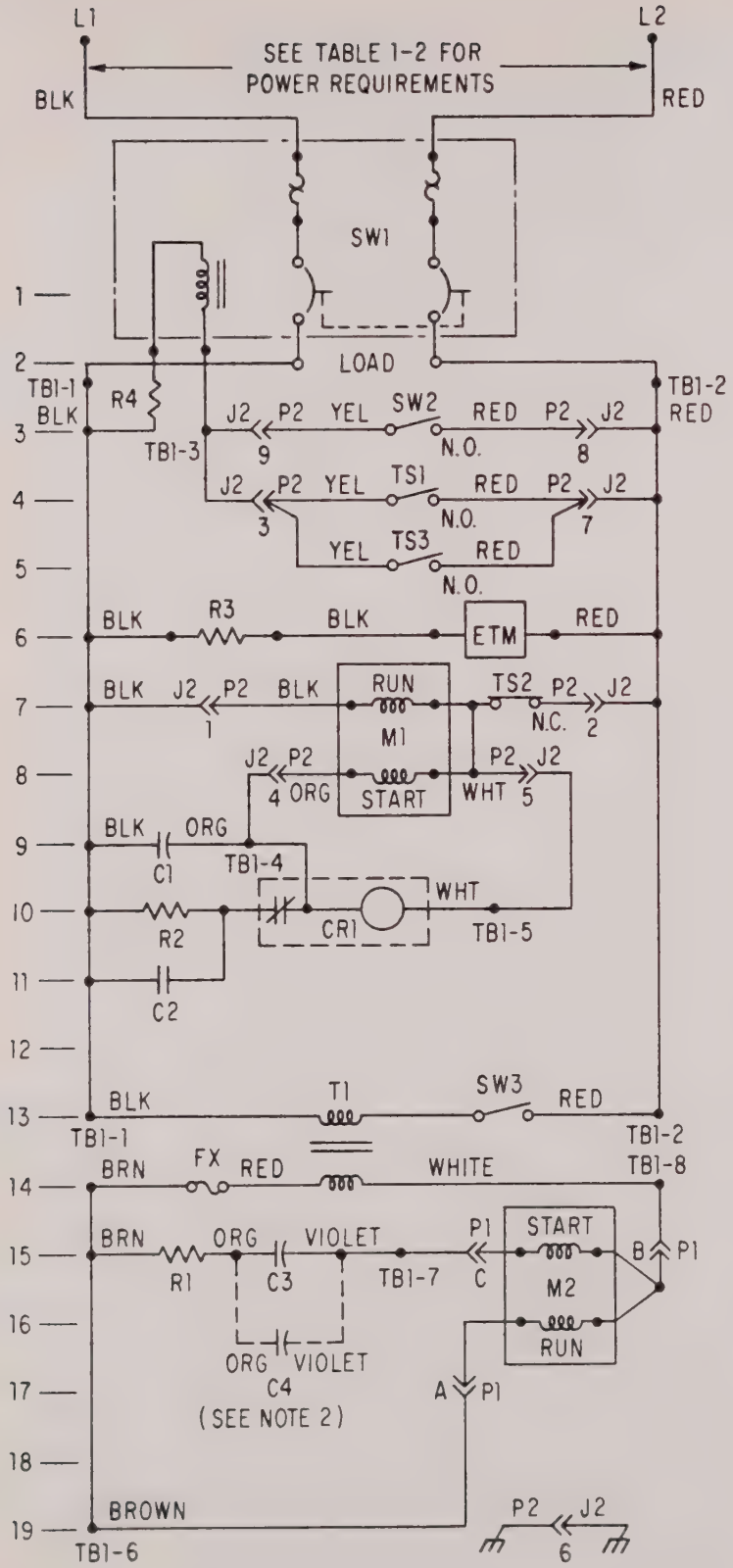
5. TROUBLESHOOTING THE MODEL 21/350SCW COMPRESSOR UNIT	7



LEGEND

C1 - COMPRESSOR-RUN PHASE-SHIFTING CAPACITOR - 25 µFD, 440 V
C2 - COMPRESSOR START CAPACITOR - 48 + 5 µFD, 330 V
C3 - COLD HEAD DRIVE MOTOR PHASE-SHIFTING CAPACITOR - 6 µFD, 330 V
C4 - COLD-HEAD-DRIVE-MOTOR PHASE-SHIFTING CAPACITOR-2 µFD, 330 V (FOR 50-Hz OPERATION ONLY)
CR1 - COMPRESSOR STARTING RELAY
ETM - ELAPSED TIME METER
FX - COLD-HEAD CIRCUIT FUSE-1 AMP
J2 - ELECTRICAL CHASSIS CONNECTOR JACK
M1 - COMPRESSOR PUMP MOTOR
M2 - COLD-HEAD DRIVE MOTOR
P1 - COLD-HEAD CABLE CONNECTOR
P2 - ELECTRICAL CHASSIS CONNECTOR PLUG
R1 - COLD-HEAD-DRIVE-MOTOR PHASE SHIFTING RESISTOR - 150 Ω
R2 - COMPRESSOR START RESISTOR - 18K Ω
R3 - BALLAST RESISTOR FOR LAPSED TIME METER - 13K Ω
R4 - CURRENT-LIMITING RESISTOR - 680 Ω, 1W
SW1 - COMPRESSOR "ON-OFF" SWITCH
SW2 - SAFETY INTERLOCK SWITCH
SW3 - COLD-HEAD "ON-OFF" SWITCH
T1 - COLD-HEAD ISOLATION TRANSFORMER 140-168 V OUTPUT
TB1 - TERMINAL BOARD (CHASSIS)
TS1 - THERMAL PROTECTIVE SWITCH - OIL FLOW
TS2 - OVERCURRENT PROTECTIVE SWITCH
TS3 - THERMAL PROTECTIVE SWITCH - WATER FLOW

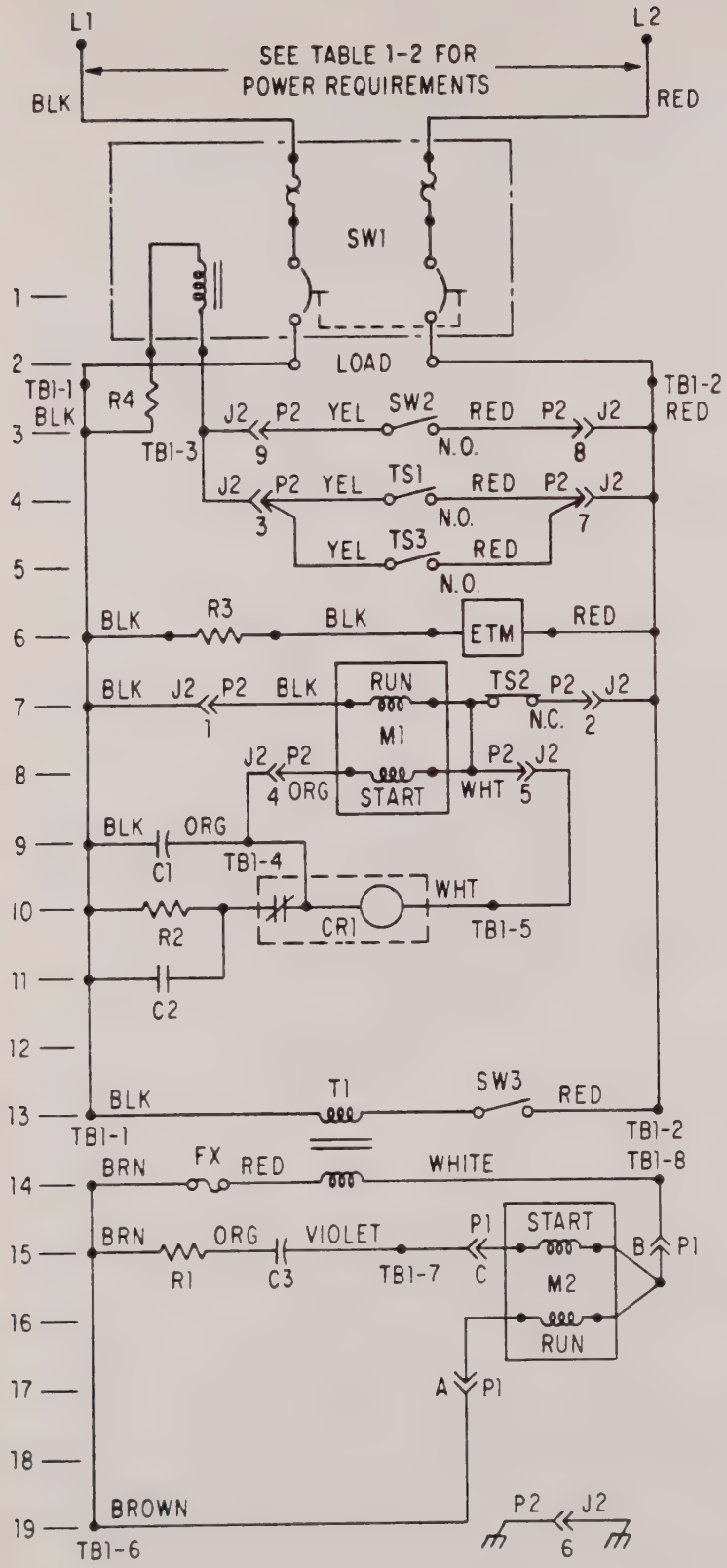
NOTES:

1. TERMINAL BOARD MECHANICAL LINKAGES ARE AS FOLLOWS:

TB1-1
TB1-1
TB1-2
TB1-2

2. C4 IS FOR 50 Hz OPERATION ONLY

FIGURE 4. ELECTRICAL SCHEMATIC FOR MODEL 350SCW COMPRESSOR UNIT PART NO. D8032096G1 OR PART NO. D8032096G2



LEGEND

C1 - COMPRESSOR-RUN PHASE-SHIFTING CAPACITOR - 25 µFD, 440 V
C2 - COMPRESSOR START CAPACITOR - 48 + 5 µFD, 330 V
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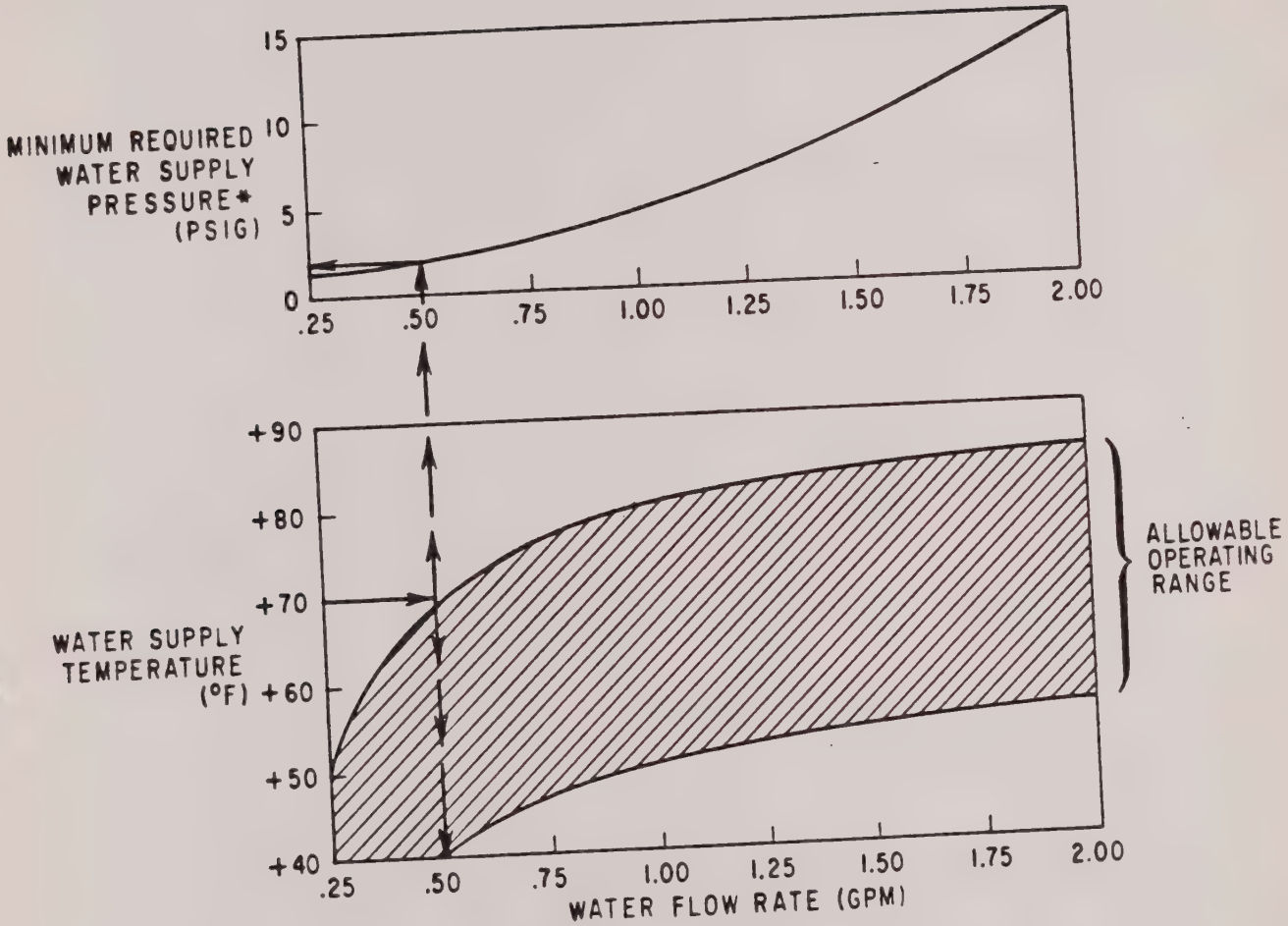
J2 - ELECTRICAL CHASSIS CONNECTOR JACK
M1 - COMPRESSOR PUMP MOTOR
M2 - COLD-HEAD DRIVE MOTOR
P1 - COLD-HEAD CABLE CONNECTOR
P2 - ELECTRICAL CHASSIS CONNECTOR PLUG
R1 - COLD-HEAD-DRIVE-MOTOR PHASE SHIFTING RESISTOR - 150Ω
R2 - COMPRESSOR START RESISTOR - 18K Ω
R3 - BALLAST RESISTOR FOR LAPSED TIME METER - 13K Ω
R4 - CURRENT-LIMITING RESISTOR - 680 Ω, 1W
SW1 - COMPRESSOR "ON-OFF" SWITCH
SW2 - SAFETY INTERLOCK SWITCH
SW3 - COLD-HEAD "ON-OFF" SWITCH
T1 - COLD-HEAD ISOLATION TRANSFORMER 140-168 V OUTPUT
TB1 - TERMINAL BOARD (CHASSIS)
TS1 - THERMAL PROTECTIVE SWITCH - OIL FLOW
TS2 - OVERCURRENT PROTECTIVE SWITCH
TS3 - THERMAL PROTECTIVE SWITCH - WATER FLOW

NOTES:

TERMINAL BOARD MECHANICAL LINKAGES ARE AS FOLLOWS:

TB1-1
TB1-1
TB1-2
TB1-2

FIGURE 5. ELECTRICAL SCHEMATIC FOR MODEL 21SCW COMPRESSOR UNIT PART NO. D8032096G3 OR PART NO. D8032096G4

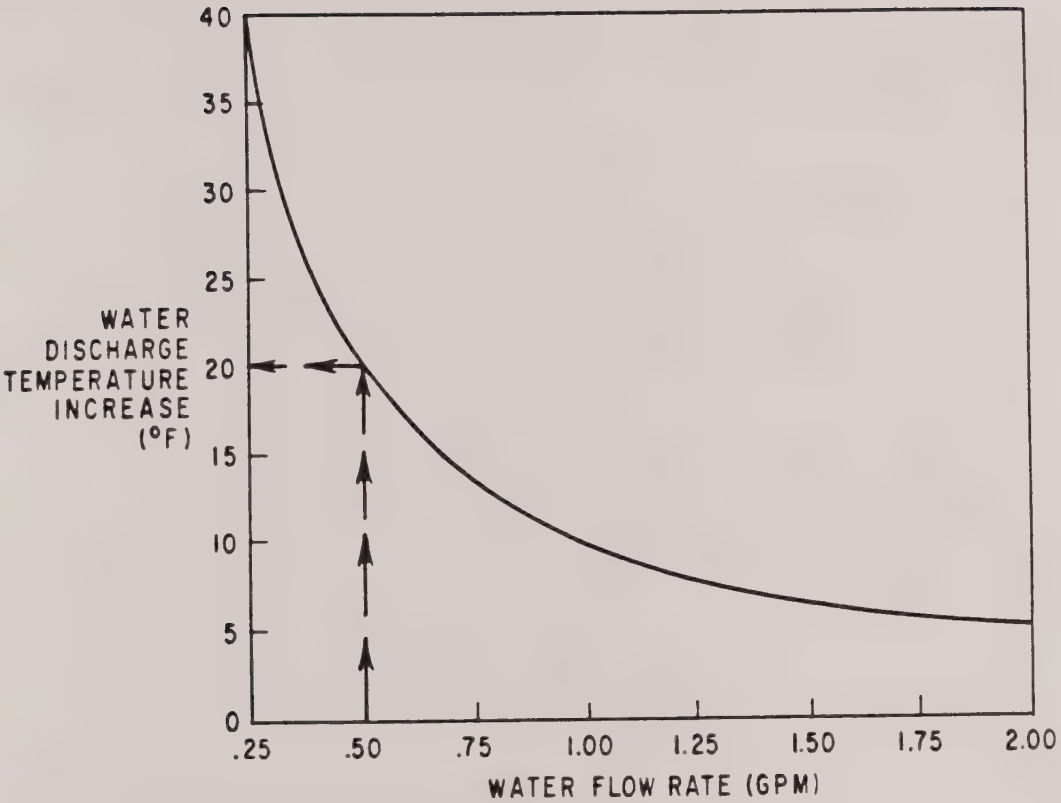


*WITHOUT CONSIDERATION OF ANY DISCHARGE BACK-PRESSURE CONDITIONS (SEE TEXT)

NOTE:

→ → → USED FOR CLARIFICATION OF EXAMPLE PRESENTED IN TEXT.

FIGURE 6. WATER REQUIREMENTS DATA FOR THE WATER-COOLED MODEL 21/350SCW COMPRESSOR UNIT



NOTE:

→ → → USED FOR CLARIFICATION OF EXAMPLE PRESENTED IN TEXT.

FIGURE 7. WATER DISCHARGE TEMPERATURE DATA FOR THE WATER-COOLED MODEL 21/350SCW COMPRESSOR UNIT

3. SELECTION OF OPTIMUM COOLING WATER PARAMETERS

If the User wishes to select the optimum water flow parameters for his particular installation (instead of the generalized guidelines in Section 2, para. (7)) he may do so by referring to procedures in Sections 3.1 through 3.3 below.

3.1 DETERMINATION OF WATER-FLOW RATE REQUIREMENTS

If the supply water temperature is maintained within a range narrower than 50° to 80°F (refer to Section 2, para. (7) above), then the water flow rate can be reduced to less than 1 gallon per minute to conserve water. The following example shows how to calculate the minimum flow rate required for a specific installation.

EXAMPLE FOR DETERMINING WATER FLOW RATE REQUIREMENT (Refer to Figure 6)

Note: The graph shown on the lower half of Figure 6 is used to calculate the water flow rate required in relation to the input cooling water temperature; while the graph on the upper half is used to determine the input cooling water supply pressure in relation to the water flow rate.

(a) Determine if possible the temperature variation of the cooling water that will be supplied to the compressor unit. In cases where this figure cannot be ascertained, allow ± 10°F to the present cooling water temperature. In the example shown on the lower graph of Figure 6, it was determined that the water supply will have a temperature variation of 70°F to 40°F.

Note: The allowable operating range (cross-hatched area) shown on Figure 6, represents the range of values of the water supply temperature that will ensure an adequate cooling capacity for the compressor unit for any specified value of the water flow rate.

(b) To determine the optimum water flow rate for these parameters, draw a horizontal line from the upper temperature limit (refer to dashed-arrow on lower graph of Figure 6) to the upper curve of the allowable operating range. Draw a vertical line down perpendicular to this intersecting point to obtain the optimum water flow rate for the compressor unit, which in this example is 0.5 gallon per minute.

3.2 DETERMINATION OF WATER PRESSURE REQUIREMENTS

The cooling-water supply pressure must be sufficient to allow a suitable flow rate, taking into account the pressure drop through the compressor unit and through the cooling water supply and return lines. The cooling-water supply pressure (that is, the water pressure at the compressor-unit inlet) should never exceed 100 psig or be less than 5 psig. To determine the minimum water supply pressure required at the water flow rate determined in 3.1 of this Addendum use the upper half of Figure 6. The required procedure is demonstrated by the following example.

LEYBOLD-HERAEUS

GA 125

11. edition

-trivac-®

S 30 A, S 60 A, D 30 A, D 60 A

104 97, 105 10, 110 75, 111 00

Please read carefully **before** *operating.*

Operating Manual

Contents

1. Technical data
2. Design and functioning
3. Standard specification
4. Connection of pump and accessories
5. Electrical connection
6. Starting-up
7. Operation
8. Switching off
9. Maintenance
10. Storage
11. Special hints for operation
12. Cleaning the pump

1. Technical data

The indicated technical data are based on the PNEUROP Acceptance Rules for vacuum pumps.

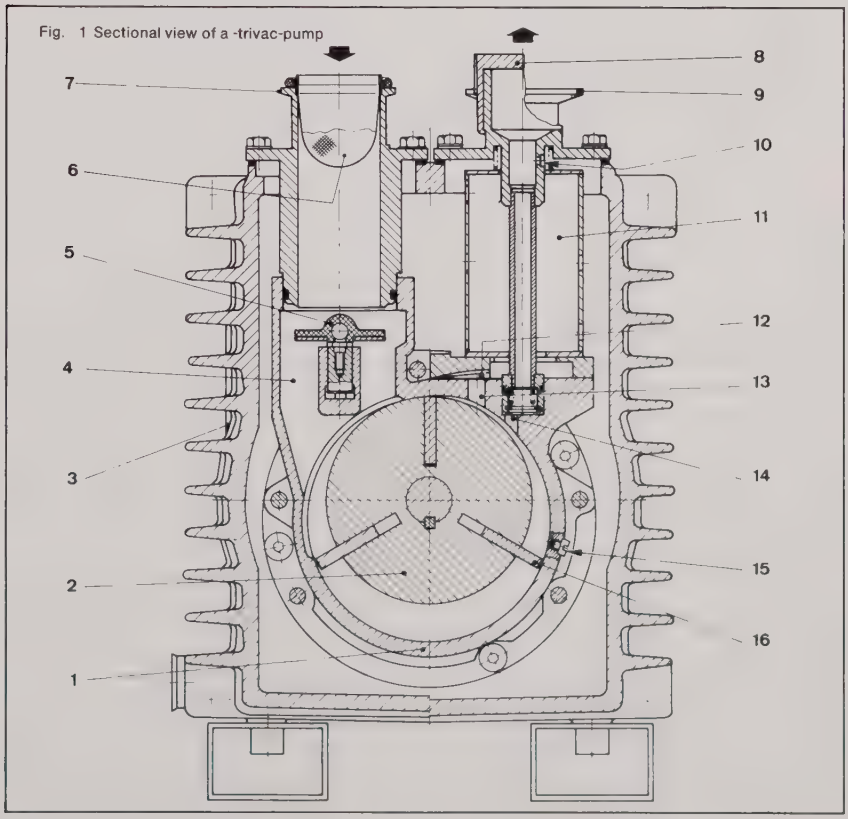
-trivac-pump		S 30 A	S 60 A	D 30 A	D 60 A
Rated pumping speed	m^3/h	38	76	38	76
Pumping speed according to PNEUROP	m^3/h	30	60	30	60
Ultimate partial pressure	mbar	$<2{,}5 \cdot 10^{-2}$	$<2{,}5 \cdot 10^{-2}$	$<2{,}5 \cdot 10^{-4}$	$<2{,}5 \cdot 10^{-}$
Ultimate total pressure with gas ballast	mbar	$<6{,}5 \cdot 10^{-1}$	$<6{,}5 \cdot 10^{-1}$	$<6{,}5 \cdot 10^{-3}$	$<6{,}5 \cdot 10^{-}$
Water vapour tolerance	mbar	40	66	40	33
Intake and exhaust ports	NW	40 KF	40 KF	40 KF	40 KF
Oil filling					
min.	ltr.	1,8	2,5	2,6	3,2
max.	ltr.	2,3	3,1	3,4	4,1
Motor power with a. c. three-phase motor	kW	1,1	2,2	1,1	2,2
Rated rotational speed	r.p.m.	1500	1500	1500	1500
Weight with a. c. three-phase motor	kg	62	77	75	90
-trivac-pump with a. c. three-phase motor	Cat. No.	104 97	105 10	110 75	111 00
Replacement pump body [1]	Cat. No.	101 64	101 65	101 70	101 71

1) see section 12.1
KF = small flange

Key to Fig. 1

1 Pump housing
2 Rotor
3 Oil level glass
4 Intake channel
5 Airing/isolation valve
6 Dirt trap
7 Intake port
8 Gas ballast valve – sealing cap
9 Outlet port
10 Secondary-air inlet, silencing
11 Oil filter
12 Exhaust valve
13 Exhaust channel
14 Gas ballast channel
15 Oil injection
16 Vanes

Fig. 1 Sectional view of a -trivac-pump



2. Design and functioning

(see Fig. 1)

The -trivac-pumps are oil-sealed rotary vane pumps. The drive motor – a flange-coupled motor design type B 5 – is directly flanged onto the pump body. Pump shaft and motor shaft are connected with one another by an elastic coupling. A fan mounted on the coupling and suitable ventiducts provide low temperatures in the region of the coupling even under extreme conditions. All bearing points are lubricated friction bearings.

The pump housing consists of assembly parts sealed from each other by O-rings. All parts are pin-fitted to ensure easy dismantling. The pump body is easy to disassemble without using special tools.

The rotor (2), mounted eccentrically in the pump cylinder (1) divides – with its three radially sliding vanes (16) – the pump chamber into several chambers. The volume of each chamber changes periodically with the rotation of the rotor.

Hereby gas is sucked in on the intake port (7). This gas passes through the dirt trap sieve (6), passes the open airing/isolation valve (5) and enters the pump chamber. In the pump chamber, the air is passed on and compressed – after the inlet aperture is closed by the vane. Oil is injected into the pump chamber through (15), a) for lubricating and sealing between pump chamber wall and sealing face of the vane and b) for lubricating and sealing the vanes (16) in the rotor (2).

The gas compressed in the pump chamber is expelled to the atmosphere through the exhaust valve (12). The oil entrained with the compressed gas is trapped in the oil filter (11). At the same time the oil is filtered and freed from mechanical contamination. By admitting secondary air – so-called "gas ballast" – condensation of vapours in the pump chamber is avoided. At the beginning of compression, the exactly dosaged gas-ballast amount is admitted at (14). Hereby the water vapour tolerance mentioned in the technical data is ensured. The gas ballast valve is opened and closed by turning the sealing cap (8)

The slap noise (oil slap) of the pump – usually occurring when attaining the ultimate pressure – is prevented by admitting also at (14) a very small amount of secondary air into the pump chamber.

If the pump stops operation, the centrifugal switch on the pump shaft opens an air tube which admits atmospheric air below the piston of the intake-port valve. The valve disc is hereby pressed against the valve seat. The line to the vacuum system is closed and the pump vented.

The built-in oil sight glass allows easy control of the oil level within the pump.

The pumps of standard specification are supplied with a.c. three-phase motors.

The standard motor is fitted with a sprag device.

3. Standard specification

When delivered, the small flange connection ports of the pump are blanked off by a rubber diaphragm. One centering ring NW 40 KF with dirt filter, one centering ring NW 40 KF and two clamping rings are supplied as a standard to connect the intake line and the discharge line.

The pumps are filled with oil N 62 when delivered.

In addition, an adapting centering ring NW 32/40 KF for the discharge port and an adapting centering ring NW 32/40 KF with dirt filter for the intake port are supplied with each pump.

4. Connection of pump and accessories

WARNING!

Before mounting the pump on to a system, remove safety wedge fitted for transport. Incline pump a little and extract wedge in downward direction.

Should the wedge be broken, remove broken part from the centrifugal switch to ensure proper functioning of the pump.

The pump is set on a plane, horizontal surface and need not be fixed to the bottom.

Before connecting the pump to the system, remove packing seals (rubber diaphragm on the connection ports) and the perforated plate in the exhaust port.

The cross-section of the connecting lines (intake and exhaust line) should at least be the same size as the connection port of the pump. If the intake line is too narrow, it will reduce the pumping speed. If the outlet discharge line is too narrow, excess pressure will be produced in the pump at high intake pressures which might damage the shaft seals and cause oil leaks.

Note!

If the pump D 60 A is to be operated in a pressure range below 10^{-3} mbar, it is recommended to provide a connection line of a nominal width of NW 50 KF. Throttling of the pumping speed is prevented by enlarging the cross-section of the pipe.

The vacuum-tight connection of the pump is of special importance, if the pump is to attain the expected ultimate pressure.

Our technical staff will gladly help you with any problems you may encounter.

If possible, the exhaust line should be installed in descending position to prevent condensate from flowing back into the pump and contaminating the oil. It is absolutely necessary to provide an exhaust trap on the pump if the outlet line is ascending.

If no exhaust line is connected, it is recommended to provide an exhaust filter.

4.1. Accessories

Condensate trap AK 30–60

NW 40 KF	Cat. No. 18815
Fittings for connection:	
Bend	Cat. No. 18438
Centering ring	Cat. No. 18328
Clamping ring NW 32/40 KF	Cat. No. 18343

optional:

Drain tap for condensate trap	
Intake side	Cat. No. 18891
Outlet discharge side	Cat. No. 18890

Exhaust filter AF 30–60 A

NW 40 KF	Cat. No. 18915
Spare filter element	Cat. No. 18980
Fittings for connection:	
Bend	Cat. No. 18438
Clamping ring 32/40 KF	Cat. No. 18343
Centering ring	Cat. No. 18328

Dust filter FS 30–60

Cat. No. 18615

Foreline sorption trap FA 30–60

Cat. No. 18715

Dust separator AS 30–60

Cat. No. 18616

Spare filter element Cat. No. 17804

Molecular filter MF 30–60

Cat. No. 18617

Spare activated charcoal filter element Cat. No. 17808

5. Electrical connection

5.1. Three-phase motor

The motor must be connected via the terminal strip. A five-core cable is recommended. This makes the separate installation of a special protective wire besides the neutral wire possible (VDE 0100/12.65 § 10 N).

If beside the motor no other electric devices (220 V) are connected, a 4-core cable 3 phases and protective wire will be sufficient.

According to VDE rules a motor protection switch must be fitted in the connection line. The setting of the motor protection switch should correspond to the indications on the rating plate of the motor.

After connecting the motor and after every change of the connection, make sure of the correct sense of rotation (see section 6).

6. Starting-up

Running in the wrong sense of rotation is prevented by a sprag device in the standard motor fitted for the pump in our works. Connection of the motor via a motor protection switch is necessary.

In case that the pump is not supplied with our standard motor, but fitted for instance with a local motor without sprag device, please check the sense of rotation of the motor. The sense of rotation of the motor should be clockwise, from left to right, when facing the fan from the back of the motor.

Switch on the motor for a **short moment** only and ascertain sense of rotation.

IMPORTANT!
The pump running in the wrong sense for too long a time will eject oil and might damage the valve plate of the built-in airing/ isolation valve (see section 8). Therefore, we recommend covering the intake port with some kind of cloth checking the sense of rotation, so as to be protected against oil splashes if any.

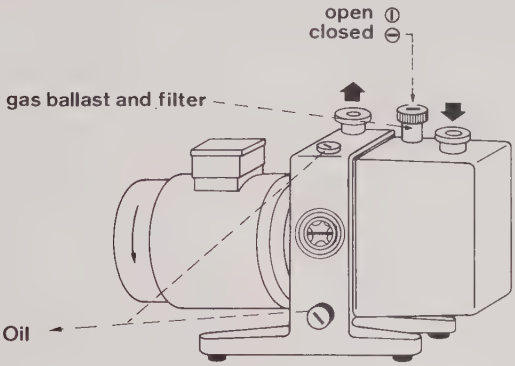


Fig. 2

Key to Fig. 3

3 Oil level glass
7 Intake port
8 Gas ballast valve
9 Outlet port
17 Terminal box (drive motor)
18 Oil filling plug
19 Oil drain plug
10 Filter device – mounting flange
21 Pump casing

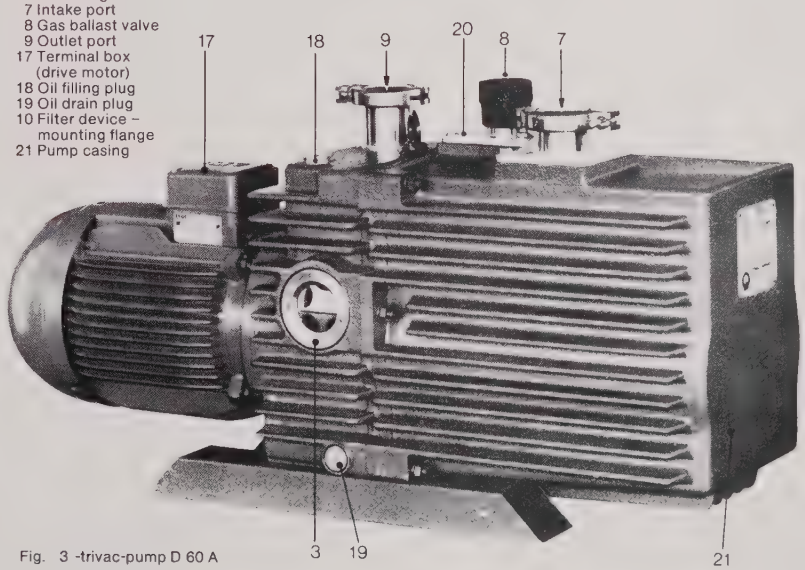


Fig. 3 -trivac-pump D 60 A

7. Operation (see Figs. 2 and 3)

7.1. Removal of vapours or vapour-containing gases

The -trivac-pump is capable of removing saturated water vapour up to the water vapour tolerance value stated in the "Technical data", when the gas ballast valve is open. The gas ballast will not become fully effective before the pump is warmed-up more than to touch. In this case, no water will condense in the pump.

When pumping oil-soluble vapours the pump oil might become saturated with condensate. This can be avoided by increasing the pump temperature, by heat insulation of the pump casing, or by increasing the amount of gas ballast. The higher water vapour tolerance obtained in this way allows virtually all solvent vapours to be pumped off.

For such applications we shall be glad to let you have our special proposals regarding the solution of your problems.

Open gas ballast valve (8)

The pump should have warmed by approx. half an hour's operation with gas ballast valve open and closed intake line before the system is connected (e.g. by opening a valve). When the pump is cold, condensation may occur in spite of the gas ballast valve being open.

When removing vapours, it is advisable always to provide a condensate trap on the intake side and also on the exhaust side (see section 4).

7.2. Removal of large quantities of water vapour

If water vapour of an intake pressure higher than the water vapour tolerance is set free, then a water-cooled condenser must be inserted in the intake line.

7.3. Removal of non-condensable gases

You can operate the pump without gas ballast when all vapours have been pumped off from the system, or when there is only a small accumulation of vapour with a large excess of permanent gases.

Due to the moisture in every system, a part of the atmosphere to be pumped off always consists of condensable vapours.

You should, therefore, run the pump for a short time with gas ballast valve still open, in order to dry the system.

Close gas ballast valve (8)

The pump will now attain a considerabl lower pressure. When the pump is operat ed against ultimate pressure with gas ba last valve closed, practically no oil will b consumed.

8. Switching-off

An airing/isolation valve fitted in the intak port of the pump shuts the intake port, whe the pump is switched off. Thus the vacuur is maintained in the connected system.

When the motor is switched off, a centrifuga switch opens the buit-in venting valve. Th atmospheric air streaming in through th venting valve passes below the plunger c the intake-port valve, and thus effects th shut-off of the intake port. At the same time the pump is vented by this instreaming a and oil suckback is prevented.

The shut-off of the intake port does not depend on the mode of operation of the pump; it also operates when the pump runs with the gas ballast valve open.

9. Maintenance (see Fig. 3)

Make sure that your pump is always filled with enough clean oil.

All pumps use more or less oil in normal operation, depending on the gas throughput.

9.1. Oil level check

Check oil level and replenish oil whenever necessary.

The minimum oil level is reached, when, with the pump running, the oil surface is visible at the lower rim of the oil level glass (3).

Maximum oil filling corresponds to an oil level up to the top rim of the oil level glass (3).

NOTE!

Check oil level when the pump is running at its ultimate pressure and without gas ballast. On a pump at standstill, the oil level appears to be lower than it really is.

9.2 Check oil for contamination

With the pump running, allow a little oil to flow through the oil drain port (19) into a beaker or similar vessel. Special oil N 62 is clear and transparent.

9.3. First oil change

The oil must be changed after the first 100 hours of operation. Under certain circumstances, a check may indicate that the oil must be changed earlier, if for instance the oil has lost its original colour.

9.4. How to carry out an oil change

Always carry out an oil change when the pump is still warm and switched off. Unscrew the oil drain plug (19) and allow the oil to drain off. When the flow of oil slows down, briefly cut in the pump – cut out again – and drain off the remaining oil. Replace the oil drain plug (19) and fill with fresh oil at (18).

We recommend the use of our special oil N 62.

For special applications, e.g. operation at higher temperature, pumping of certain media such as solvents, oxygen etc., the use of special oils is advisable. In such cases please contact us for detailed information.

9.5. Further oil changes

Further oil changes are required only, if the oil is dirty (for oil change see section 9.4).

If the oil is very dirty, flush out the running pump with clean pump oil before filling it with fresh oil. For this purpose fill the fresh oil into the intake port (7) of the running pump. Let the pump run for at least 10 minutes and drain oil again. If it is still dirty repeat the process.

If the pump oil is mixed with a little water or oil-soluble substances, let the pump run for some time with the intake port (7) closed but the gas ballast valve (8) open. In this way, liquids such as water, alcohol, petrol (gasoline), benzene and carbon tetrachloride etc. will be removed from the oil.

9.6 Dirt trap

A wire mesh filter is placed in the intake port (7) of the pump as a dirt trap for coarse contamination. It should be kept clean all times, in order to avoid reduction of the pumping speed.

If you have detached the intake line, the dirt trap can easily be removed from the intake port (7).

Note!

In normal operation and when inspecting the pump, do not forget to clean the dirt traps or exhaust filters respectively, if any.

A contaminated exhaust filter is inefficient.

If the condensate is not drained in time from the traps, it will flow from the pressure-side trap into the pump or re–evaporate from the intake-side trap.

10. Storage

When the pump is laid off for a lengthy period, the oil must first be drained off, then flush out the pump and fill it with the necessary quantity of clean oil.

Fill up with fresh oil as outlined in section 9.4. It is advisable to close the connection ports dirt-proof. N 62 is the most suitable oil for preservation.

11. Special hints for operation

Our standard rotary vane vacuum pumps are resistant to solvents.

The sturdy construction of the pumps allows to increase the operating temperature to approx. 90° C for pumping vapours. This will increase the water vapour tolerance by about a factor of ten. Suitable heat insulations can be supplied. Please contact us for your special problem.

11.1. Pressure measurement

Each pump is thoroughly tested by us by means of measurements as specified in the PNEUROP Acceptance Rules. We guarantee the specified performance. If you fail to obtain these specified performance values in your system, measure the ultimate pressure directly at the intake port of the pump. In order to do this, shut off the pump from the system.

Note: The ultimate pressure of the non-condensable gases (ultimate partial pressure of air) can be measured by a compression-type vacuum gauge.

THERMOTRON®, THERMOVAC and similar electrical gauges measure the total pressure which is practically determined by the vapour pressure of the oil.

11.2. Self-purification of the pump

Dirty pump oil, e. g. contaminated by vapours or solvents, can lead to an unsatisfactory ultimate pressure.

The oil is regenerated and the efficiency of the pump restored by gas ballast operation with the intake line shut off.

If the oil is very dirty it is advisable, however, to change the oil and to clean the pump completely.

11.3. Leak test

We recommend also leak-testing in the system e. g. by means of a pressure rise test, a halogen leak detector or similar methods. Corresponding recommendations are given in Operating Instructions GA 998 which will be sent to you on request.

11.4. Ultimate pressure of pump

When the pump is first used after a lengthy lay-off or following an oil change, it will only attain the specified ultimate pressure after a certain time has elapsed. The pump must first reach its operating temperature, and the oil must be degassed. The temperature of the pump is higher when operated with gas ballast valve open than when it is run with gas ballast valve closed; depending upon the mode of operation, this temperature may rise up to 95°C.

At all events, it is advisable to operate the pump at first with gas ballast valve open.

11.5. Moisture in the system

If moisture in the system is responsable for the pump not attaining the expected vacuum, this can be remedied by operating with gas ballast valve open.

11.6. Oil ejection of pump (see Fig. 1)

If the pump ejects oil, this may be due to the pump being overfilled with oil. Check oil level according to section 9.1. The contamination of the built-in filter cartridge (11) may also be the cause of excessive oil consumption.

If this contamination is excessive, the filter cartridge may clog up. This will create an overpressure in the cartridge, which will push it slightly from its seat, so that the filter cartridge is bypassed by the exhausted gases towards the outlet.

11.7. Exchange of filter cartridge

(see Fig. 3)

The filter cartridge may easily be taken off upwards after unscrewing the bolts on the mounting flange (20) of the filter device. If difficulties should arise in taking off the filter cartridge, push by a screw driver inserted below the flange edge.

Take off filter cartridge and clean it or replace it by a new one.

Assembly is made in the reverse order.

Before placing the filter device into the pump housing, wet O-ring with oil.

12. Cleaning the pump

(see Fig. 3)

12.1. Diassembly

Drain off the oil with the pump being warm. For fully emptying the pump, cut in the pump for a brief moment with open intake port. Unscrew mounting flanges of intake port (7) and filter device (20).

Take off intake port (7) and filter device (20).

If difficulties should arise when taking off the intake port, you may assist with a screw driver placed below the flange.

For disassembling the filter device see section 11.7.

Unscrew nuts on pump casing (21) and pull it off. Unscrew the socket head cap screws at the shaft bearing plate and remove the entire pump body from the housing of the shaft coupling. Let valve disc with piston of the airing/isolation valve fall out.

If necessary, the inner pump body should be replaced by a new one.

For replacement pump bodies see Section 1, Technical Data.

12.2. Cleaning

We recommend to use cleaning spirit. When using other cleaning agents make sure they do not attack the gaskets - VITILAN. Thoroughly wash all disassembled parts in the cleaning fluid and dry.

The pump body is cleaned as a whole. For this purpose fill in the cleaning agent through the intake port and turn round the rotor by hand. The pump body should be entirely drained and dried before reassembling.

12.3. Assembly

Replace valve disc and piston correctly into the pump body. Fill in a little oil through the intake port into the pump body and turn the rotor by hand.

Now the pump body is screwed again to the coupling shaft housing. Make sure thereby that the coupling halves are correctly fitted into each other, which means that the elastomer cushions must be refitted into their original position where they are exposed to compressive load or to tensile load respectively. Beware also that the lever actuated by the centrifugal switch is not bent. Replace the pump casing and tighten socket head cap screws.

Wet O-ring and sealing surfaces on the intake port with oil and fit the latter by hand into the pump housing and tighten.

Fill in the required quantity of oil through the inlet aperture of the filter device, insert the filter device and tighten (assembly of filter device see section 11.7).

Close the intake port (7) vacuum-tight and let the pump operate for approx. one hour with the gas ballast valve (8) open.

Servicing
To help you keep your pump in top condition, we recommend the conclusion of a Servicing Contract. Your pump will then be checked by our servicing personnel according to the conditions agreed upon
Details will be given on request.

General Note
We reserve the right to change at any time the dimensions and data given in these instructions.
The illustrations are not binding.

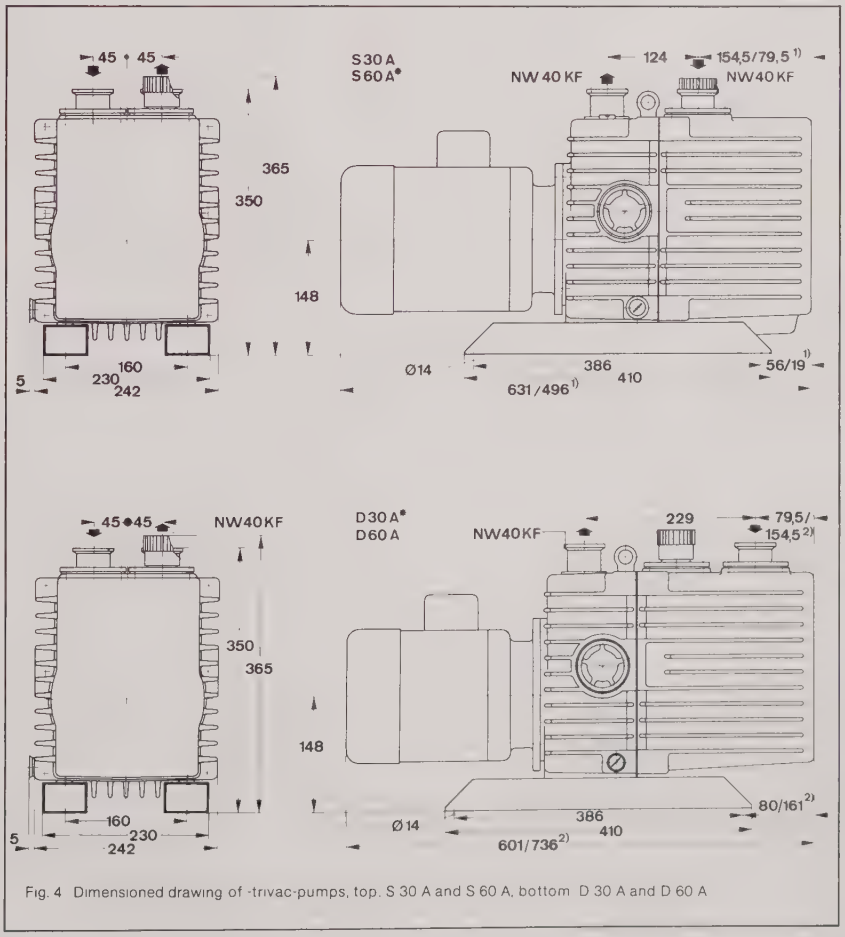


Fig. 4 Dimensioned drawing of -trivac-pumps, top. S 30 A and S 60 A, bottom D 30 A and D 60 A

LEYBOLD-HERAEUS

LEYBOLD-HERAEUS GMBH · KÖLN
Bonner Straße 504 Postfach 510 760 D-5000 Koln 51 (Bayenthal)
Telefon (02 21) 3 70 11 · Telex 8-882 815 ley d Draht leyboldheraeus koln

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Wilhelm-Rohn-Straße 25 Postfach 549 D-6450 Hanau Telefon (0 61 81) 36 41
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TECHNICAL MANUAL

for

DISPLEX CLOSED-CYCLE REFRIGERATION SYSTEM

MODELS CSA-202, CSW-202 and HV-202

Manufactured by

Air Products and Chemicals, Inc.
APD - Cryogenics
1919 Vultee Street
Allentown, Pennsylvania 18103

Air Products

August 1979

LIST OF PRECAUTIONS

The Displex Refrigeration System is a precision piece of equipment requiring informed personnel for its successful operation and maintenance. The following list of precautions should be known and observed by all operating and maintenance personnel.

Do not start the refrigeration system until this handbook has been completely read and understood.

Precautionary notes used in the handbook are defined below along with a summary of the most important notes.

WARNING

Failure to adhere to these precautions may result in injury to personnel. It is therefore Air Products and Chemicals, Inc. recommendation that:

a. Only skilled technicians remove the compressor cover when the compressor is operating.

b. Only qualified electricians remove the electrical box cover when power is connected.

c. No component be disassembled or removed until all gas is vented from internal working volume(s).

d. The main power be disconnected from the refrigeration system before working on any electrical component.

e. Transfer of cylinder helium to the refrigeration system only be done with the use of the proper pressure regulator.

f. The gas lines never be disconnected from the expander unless the expander is at room temperature.

CAUTION

Failure to adhere to these precautions may result in damage to the equipment.

a. Avoid twisting of flexible gas lines.

NOTE

Failure to adhere to these precautions may result in maintenance, not requiring replacement parts.

a. Always use grade "A" helium (99.995% pure) with a dew point less than −80°F.

b. Never operate the refrigeration system with a charcoal adsorber that has been used over 9,000 hours.

c. Do not leave compressor internals exposed to ambient air.

WARRANTY

Seller warrants the equipment manufactured by it to be free from defects in material and workmanship at the time of shipment from Seller's factory and for a period of one (1) year thereafter, under proper and normal use and service. If, during such period, any part of such equipment is found to have been defective or damaged at the time it was shipped, it will be repaired or replaced by a similar part f.o.b. point of manufacture provided that Buyer gives Seller immediate written notice upon the discovery of any defective or damaged items, whereupon Seller shall have the option of requiring the return of the defective material to establish the claim.

As to all apparatus and products not manufactured by Seller which are a part of the equipment furnished by Seller, Seller's only obligation shall be to obtain for Buyer such warranties or guarantees as are available from the manufacturers. Such warranties or guarantees shall extend over the longest period of time obtainable, and Seller shall use reasonable efforts to require its vendors to fulfill the obligations of their warranties or guarantees on equipment and material furnished hereunder.

The replacement or repair of defective parts, as aforesaid, shall be Buyer's only remedy for breach of the material and workmanship warranties of Seller. As to the equipment of other manufacturers, resort shall be had against such manufacturers only. No allowance will be made for repairs or alterations made without the written consent of Seller, in which event all Seller's warranties hereunder shall be void and of no effect. Buyer agrees to assume responsibility and pay for such defects which are attributable to it and for damages which may occur to the equipment after delivery to it.

All warranties as to material and workmanship are expressly set forth herein and are in lieu of any warranty of fitness for a particular purpose and all implied warranties save for the implied warranties of Seller's title, its right to transfer the equipment, and the freedom thereof from encumbrance. Seller shall not be liable for special, indirect or consequential damages of any kind, or for any damages arising from the normal use or the misuse of the equipment.

Items returned for repair or replacement should be shipped, freight charges prepaid, to the following address:

Air Products and Chemicals, Inc.
APD - Cryogenics
1919 Vultee Street
Allentown, Pennsylvania 18103

Equipment should be packaged and labeled to eliminate possible damage during shipping. It is recommended to use the original shipping container to return all equipment.

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SECTION 1
INTRODUCTION

This technical manual describes the operation and maintenance of the Displex® group of cryogenic refrigeration systems. This includes the following:

CS-202 Two-stage refrigerator capable of 10°K

HV-202 Cryopump Systems

NOTE

All of the above systems can be supplied with either air or water cooled compressor.

Your particular system has been manufactured by skilled technicians and is based on experienced engineering design and technological innovations. The system is designed for ease of operation and maintenance as well as easy interface with a variety of research equipment and vacuum apparatus. Air Products' closed-cycle refrigeration systems are recognized for quality and performance in university and industrial research. Figure 1-1 displays the basic components of the two-stage system.

The major sections of this manual are designed to give you complete instructions on installation, operation, and maintenance of the basic system and accessories. It is recommended that this handbook be read completely before operating the system. The manual has been written with brevity and conciseness in mind. A careful reading will give the user confidence in his ability to operate the system successfully from the outset.

A brief description of each of the major sections is outlined below.

SECTION 1 INTRODUCTION

A brief introduction and outline of the manual.

SECTION 2 SPECIFICATION, THEORY, AND EQUIPMENT DESCRIPTION

The description of physical characteristics and performance capabilities of the system is presented. Also discussed is a general theory of operation for both the compressor and expander modules. A brief description of equipment items is included.

SECTION 3 INSPECTION AND INSTALLATION

Procedures for inspection, setting up the system, insulating the expander module, and connecting gas lines are described. This covers the initial installation and setup of a new system.

SECTION 4 OPERATION AND TROUBLESHOOTING

Descriptions of startup procedure, operation under steady conditions, and monitoring performance are presented. Discussions of changes in steady conditions, normal shutdown, and unplanned shutdowns and restart are also included. Following the error-fault tables and associated corrective procedures presented in this section will generally allow the operator to make his system operational after an upset or malfunction has occurred.

SECTION 5 MAINTENANCE

Two basic types of maintenance are described: scheduled and unplanned. The scheduled includes required items on both the refrigerator and compressor modules. The unplanned maintenance includes several general procedures. These procedures cover special maintenance items which are infrequently required.

SECTION 6 DISPLEX CRYOPUMP SYSTEM
Procedures for setting up, operating, and maintaining all Displex Cryopump Systems are presented.

SECTION 7 INTERFACE ARRANGEMENTS
Description of interface arrangements for the Displex Systems including vacuum shrouds, radiation shields, sample holders, and instrumentation. This section also covers replacement procedures for heaters, thermocouples, and sensors.

APPENDICES

APPENDIX A
This appendix contains a complete list of spare parts for all basic equipment items. The parts are identified by using the accompanying photographs.

APPENDIX B
A list of spare parts required for the standard, scheduled maintenance procedures is contained in this appendix.

APPENDIX C
The Displex system is supplied with a standard installation kit for use by the customer in setting up the system. This appendix contains a list of these items for an air-cooled and water-cooled system.

APPENDIX D
This appendix has millivolt tables for standard thermocouples and a calibration curve for a hydrogen vapor bulb.

APPENDIX E
Several temperature control and readout accessories are available with the Displex systems. Specific instructions are included for the accessory which is supplied with each system.

Figure 1-1 CSA-202 Cryogenic Refrigeration System

SECTION 2
SPECIFICATIONS AND THEORY OF OPERATION

The Displex is a closed-cycle cryogenic refrigeration system employing helium as a working medium. The system furnishes a variable amount of refrigeration between room temperature (300°K) and 10°K. The system consists of a compressor module with electrical controls, flexible interconnecting gas lines, and the expander module.

2.1 SYSTEM SPECIFICATIONS.

2.1.1 Compressor Module — Water-Cooled. The compressor module includes a one-cylinder, hermetic, oil-lubricated compressor designed for use in commercial air conditioning systems. The compressor operates on single-phase, 50/60 Hz power, is rated at 1 HP and requires 208V ∓ 5% input for 50Hz supply and 230V ∓ 5% input for 60 Hz supply. All systems are equipped with a 208/230V transformer. On units shipped domestically this is connected to boost the more common 208V power to 230V. On export units this is connected in reverse to drop the more common 230V to 208V. Total compressor power requirement is 1.8 KW or less. Figure 2-1 shows typical compressor performance in terms of mass flow as a function of suction and discharge pressure. Ambient operating temperature range is 40-100°F.

a. OIL. The type of oil used in the compressor is a synthetic lubricant, UCON LB-300-X manufactured by Union Carbide Corporation. There is an internal oil pump in the compressor for bearing lubrication. No external oil pump is used on this system. Normal oil charge is 1700 CC.

b. OIL SEPARATION. There are two stages of oil separation: first-stage glass wool oil coalescer; and second-stage charcoal adsorber. Oil is returned from the first-stage separator to the compressor through a capillary tube. Capillary size based on a .28 scfm flow rate of helium at 100 psid.

c. HEAT REJECTION. Heat developed during the compression process is rejected by a heat exchanger wrapped around the case and secured with high conductivity epoxy. The after-cooling of the high-pressure helium stream is accomplished by a heat exchanger wrapped over the water circuit and held in place by the same means. Maximum allowable inlet water temperature is 80°F, with a minimum flow of 0.4 gpm. The maximum allowable pressure, in a closed system, is 150 psig. See figure 2-2 for cooling water requirements at different temperatures and flows.

d. CONTROLS AND INSTRUMENTATION. The compressor module is equipped with the following electrical controls, indicators and shutdown instrumentation:

(1) Self-contained electrical control box containing all components required for operation of the compressor and expander module.

(2) Two electrical cables: expander module power cable (15 ft.); and compressor module power supply cable (12 ft.). The power supply plug is a 3-wire type with U shaped grounding blade (Hubbel No. 5666-C).

(3) High and low pressure gauges.

(4) Current overload and high temperature shutdown on compressor case, opens at 135° ∓ 5°C, automatically resets at 78° ∓ 9°C.

(5) Low suction pressure shutdown switch set at 85 ∓ 5 psig. Manual reset button is accessible on the right hand side of the compressor module.

(6) High discharge pressure shutdown switch set at 375 ∓ 10 psig. Manual reset button is accessible on the right hand side of the compressor module.

(7) Internal relief valve between high and low pressure set to reseat at 205 ∓ 5 psig and crack at 220 ∓ 10 psig.

(8) Atmospheric relief valve, on low pressure volume, set at 250 ∓ 5 psig, reseats at 230 ∓ 5 psig.

(9) Inlet water solenoid valve, normally closed, opens whenever the system start switch is in the "ON" position and power is connected.

(10) High-temperature automatic shutdown switch located on gas discharge line. This device shuts down the compressor on high gas discharge temperature but allows continued water flow. Opens at 110°F, automatically resets at 90°F.

(11) Elapsed time meter.

e. SIZE AND WEIGHT. Compressor module dimensions 19¼" high (with casters) x 20¼" lg x 17¼". Compressor module weight 156 lbs. excluding water.

f. MOUNTING. Unit can be mounted ∓ 20° from horizontal.

g. CONSTRUCTION. Compressor, piping, vessels, and other equipment are mounted on a steel base. Front and back panels bolt to the base and U-shaped cover is removable. Swivel casters add approximately 2" to the overall height.

h. MAINTENANCE. Oil Coalescer — Operates indefinitely, no regular maintenance interval. Charcoal Adsorber — At 9000-hour operating intervals, the entire adsorber must be replaced. Compressor — No regular maintenance interval. Average life is 30,000 hours.

2.1.2 Compressor Module — Air-Cooled. The compressor module includes a one-cylinder, hermetic, oil-lubricated compressor designed for use in the commercial air conditioning systems. The compressor operates on single-phase 50/60 Hz power, is rated at 1 HP, and requires 208V ∓ 5% input for 50 Hz supply and 230V ∓ 5% input for 60 Hz supply. All systems are equipped with a 208/230V transformer. On units shipped domestically this is connected to boost the more common 208V power to 230V. On export units this is connected in reverse to drop the more common 230V to 208V. Total compressor power requirement is 1.8 KW or less. Figure 2-1 shows typical compressor performance in terms of mass flow as a function of suction and discharge pressures. Ambient operating temperature range is 40-100°F.

a. OIL CIRCULATION. The system has an internal compressor oil pump for bearing, lubrication, plus an external pump with flow capacity of 0.4 gpm at a pressure head of 17-20 psi. Synthetic lubricant, UCON LC-300-X, suitable for long term service with helium is used for lubrication and cooling. Normal oil charge is 1700 CC.

b. OIL SEPARATION. There are two stages of oil separation: first-stage glass wool oil coalescer; and second-stage charcoal adsorber. Oil is returned from the first stage separator to the compressor through a capillary tube.

c. HEAT REJECTION. Heat developed during the compression process is rejected by two streams exchanging heat with the ambient in an air-cooled heat exchanger. The hot discharge gas is cooled in the upper part of the heat exchanger and the hot oil from the compressor crank case is cooled in the lower part. Air is drawn through the cooling coil from the front of the unit by a motor driven fan and discharged out the back. The air flow rate is

approximately 600 cfm.

d. CONTROLS AND INSTRUMENTATION. The compressor module is equipped with the following electrical controls, indicators and shutdown instrumentation:

(1) Self-contained electrical control box containing all components required for operation of the compressor and expander module.

(2) Two electrical cables: expander module power cable (15 ft.) and compressor module power supply cable (12 ft.). The power supply plug is a three-wire type with U-shaped grounding blade (Hubbel No. 5666-C).

(3) High and low pressure gauges.

(4) Current overload and high-temperature shutdown on compressor case. Opens at 135° ∓ 5°C, automatically resets at 78° ∓ 9 °C.

(5) Low-suction pressure shutdown switch set at 85 ∓ 5 psig. Manual reset button is accessible on the right hand side of the compressor.

(6) High discharge pressure shutdown switch set at 375 ∓ 10 psig. Manual reset button is accessible on the right hand side of the compressor.

(7) Atmospheric relief valve, on low-pressure volume, set at 250 ∓ 5 psig. Reseats at 230 ∓ 5 psig.

(8) Internal overload protector on oil circulating pump motor.

(9) Internal relief valve between high and low pressure set to reseat at 205 ∓ 5 psig and crack at 220 ∓ 10 psig.

(10) Elaspsed time meter.

e. SIZE AND WEIGHT. Compressor module dimensions 19¼" high (with casters) x 20¼" lg x 16¼". Compressor module weight 165 lbs.

f. MOUNTING. Unit can be mounted ∓ 20° from horizontal.

g. CONSTRUCTION. Compressor, piping, cleanup vessels, and other equipment are mounted on a steel base. Front and back panels bolt to the base and U-shaped cover is removable. Swivel casters add approximately 2" to the overall height.

h. MAINTENANCE. Oil Coalescer — Operates indefinitely, no regular maintenance interval. Charcoal Adsorber — At 9000-hour operating intervals, the entire adsorber must be replaced. Compressor — No regular maintenance interval. Average life is 30,000 hours.

2.1.3 Interconnecting Lines. The two flexible lines connecting the compressor and expander modules are corrugated tubing with an exterior bronze braided sheath. Standard length is 10 ft. with self-sealing fittings at both ends. The lines are nominal ⅜" I.D. with an external diameter of ¾". The lines are shipped cleaned, sealed, and pressurized to normal system operating pressure of 215 ∓ 5 psig.

2.1.4 Expander Module. The expander module is the refrigeration producing mechanism in the system. It has a reciprocating expander which is gas-actuated and gas-loaded. The free-floating piston assembly has the advantages of minimal mechanical complexity and lightly loaded seals. An orifice-surge volume combination contained in the expander module controls the piston motion and dissipates the work energy produced in the refrigeration process.

a. POWER. The expander module requires single-phase 208/230V, 50-60 Hz power for operation of the valve motor. This power is supplied by an interconnecting cable from the compressor module and is included in the overall system power requirement of 1.8 KW.

Power consumption of the expander module itself is 50 watts.

b. PERFORMANCE. Typical cooldown and capacity curves are shown in Section 4.2.

c. SIZE AND WEIGHT. Figure 2-3 illustrates the overall dimensions of the DE-202 expander module, without any of the special mounting arrangements. Weight of the expander assembly is 17 pounds, not including the interconnecting lines and cable or vacuum shroud. Typically the vacuum shroud weighs 4 lbs.

d. MOUNTING ARRANGEMENTS. The DE-202 expander module may have anyone of three basic mounting arrangements: basic square flange; double O-ring skirt; or high vacuum flange. These arrangements and pertinent dimensions are shown in Figure 2-4. The module can be mounted in any orientation when installed.

e. INSTRUMENTATION CONTROLS AND ACCESSORIES. Temperature readout and control instrumentation are not part of the basic system. Since the interface for each customer's system may be unique, the specification and description of all accessories are contained in Appendix E. The descriptive matter in the Appendix corresponds to the equipment furnished as part of your system.

f. AMBIENT TEMPERATURE RANGE. 40 to 100°F

g. MAINTENANCE. The seals and the valve disc are the wearing parts of the expander module. Present operating data indicates an initial wearing-in period for new seals, after which the wear rate becomes very small. It is supposed that this drop-off in wear rate is due to the successful deposition of a Teflon coating on the cylinder walls and the valve stem from the carbon-filled Teflon seals and valve disc. Although it is recommended that a set of seals and a spare valve disc be procured, it is also recommended that replacement be performed only when performance degradation so indicates.

If performance is not noticeably degraded at the completion of 9,000 hours of operation it is acceptable to continue running until performance is affected. In so doing, there is no additional risk of damage to the machine.

Specific maintenance instructions are included in Section 5.0.

2.2 THEORY OF OPERATION.

The refrigerator is a three-piece cryogenic expander based on a concept first described by E. Solvay in 1886. This three-piece system permits flexibility by having a small expander conveniently mounted while compressor and controls are remotely located. A set of flexible interconnecting lines serves to supply and return gas between the expander and compressor.

2.2.1 Compressor Module. The compressor is a converted air conditioner type of Freon compressor which is oil lubricated. The heat captured by the oil is removed either by heat exchange with the ambient air or the use of a compressor water jacket. Approximately 80% of the heat to be rejected comes from the oil, the remainder from the helium. Oil is removed from the helium by passing it through a glass wool packed column that agglomerates and separates the oil in droplet or mist form. The oil is then returned to the compressor through a capillary tube which also bypasses about 3% of the compressor flow. The oil separator removes all of the oil except that in vapor form, which has a partial pressure corresponding to less than 1 ppm. The adsorber is packed with charcoal to trap some of this residual oil vapor and with molecular sieve to trap water as it desorbs from materials within the system. One advantage of the regenerative type of heat ex-

changer contained in the expander is that it is self-cleaning and tolerant to small amounts of oil, water vapor, and air.

Figures 2-5 and 2-6 are flow and instrumentation schematics for the two types of compressor modules.

2.2.2 Expander Module. The Displex Expander matches well with the air conditioning type compressor because the efficiency is good at the pressure level and pressure ratio available in these compressors. The desirable attributes of the Solvay cycle have more recently been recognized and refined by Taconis and Gifford and McMahon. In the present adaptation of the Solvay cycle, the principal advantage is the fact that mechanical complexity and heavily loaded seals and bearings have been eliminated. The basic simplification over the previous Solvay cycle expanders consists of replacing the crank shaft and generator loader with an orifice surge volume combination which both controls the displacer motion and dissipates the work energy produced in the refrigeration process. Figure 2-7 shows a schematic diagram of the DE-202 expander and demonstrates the functional features of the system.

Refrigeration is produced in the expander by maintaining the pressure in the surge volume at value P_i, intermediate to the compressor discharge pressure, P_H, and suction pressure P_L; then proceeding through the cycle described below (Reference Figure 2-8). The process is the same for both stages, although only the first-stage operation is described here.

a. With the displacer at the cold end and gas at pressure P_i filling the volume at the warm end of the displacer, the inlet valve is opened. High-pressure gas flows down through the regenerators, where it is cooled to the temperature at which refrigeration is available, T_C. The displacer is pushed rapidly towards the warm end, compressing the gas in the warm volume to pressure P_H.

b. The displacer then moves at constant velocity towards the warm end as gas bleeds through the orifice into the surge volume.

c. Before reaching the warm end, the inlet valve is closed; the gas in the cold volume expands to approximately P_i; and the displacer is decelerated.

d. The exhaust valve is opened, causing the gas in the cold volume to expand and leave at a temperature lower than the entering temperature. This cold gas provides refrigeration at T_C and then cools the regenerator matrix as it flows out. During this phase of the cycle, the warm volume pressure drops to P_L and the displacer moves toward the cold end as gas begins to flow back through the orifice from the surge volume.

e. The displacer moves toward the cold end at constant velocity as gas continues to bleed through the orifice from the surge volume and cold gas flows out through the regenerator.

f. The exhaust valve is shut before the displacer hits bottom, thus achieving a partial recompression and decelerating the displacer. The displacer remains at the cold end for a brief period while the gas pressure in the warm volume increases to P_i. The cycle is then repeated. Work energy which is dissipated to heat by throttling in the orifice is removed by heat exchange to the exhaust gas as it leaves the unit.

In the expander, timing and flow-switching between high and low pressure is accomplished by a dual-ported rotary valve disc. This valve is continually self-seating and provides fixed cycle timing. Valve speed is 72

rpm and causes the displacer to cycle at the rate of 144 rpm on 60-cycle power. Valve speed is 60 rpm and displacer speed is 120 rpm on 50-cycle power.

The absence of linkages results in a mechanically simple unit which is easy to service. It can also be recognized that since the displacer is unrestrained, the pressure difference across the seals is very small while the displacer is moving. This, combined with low speed, results in long seal life and high reliability.

The surge volume is located above the refrigerator warm flange as part of the valve motor housing. Pressure is maintained in the surge volume at P_i by a capillary tube.

The second stage for producing refrigeration at the lower temperature is obtained by extending the displacer in a smaller diameter. This displacer extension has its own regenerator and seal. It operates through the same cycle as the first stage which maintains the "warm" end of the second stage at a low temperature.

2.3 EQUIPMENT DESCRIPTION.

This section contains a series of photographs of the Displex system with the intent of familiarizing the user with the location and identity of various equipment items. Detailed parts lists are given in Appendix A. The focus is primarily on the compressor module, since it has the greater complexity of components. The components of the expander module are adequately described in Figures 5-1, 5-2, 5-3, and 5-4.

The two basic types of compressor modules, air-cooled and water-cooled, are interchangeable in any Displex system; thus, a two-stage expander, DE-202, may use either an air-cooled or water-cooled compressor.

Figures 2-9 and 2-10 show two views of the basic air-cooled compressor module with the outer cover removed. Figures 2-11 and 2-12 are similar views of the water-cooled compressor.

Figures 2-13 and 2-14 show overhead views of the air-cooled and water-cooled compressor modules. In these two views the electrical box and cover have been removed to give a better view of other components.

Figure 2-15 shows the electrical box as a separate item. This box is common to both the air- and water-cooled units. Schematic wiring diagrams for the air- and water-cooled units are shown in Figure 2-16. These wiring diagrams show the electrical system wired for use with a 208V, 60 Hz power supply. The booster transformer increases the input voltage to 230V. All domestic U.S. units are wired in this manner. All export systems are wired with the transformer set up to step down the line voltage. Specific instructions for export systems are contained in Section 3-1, compressor module installation.

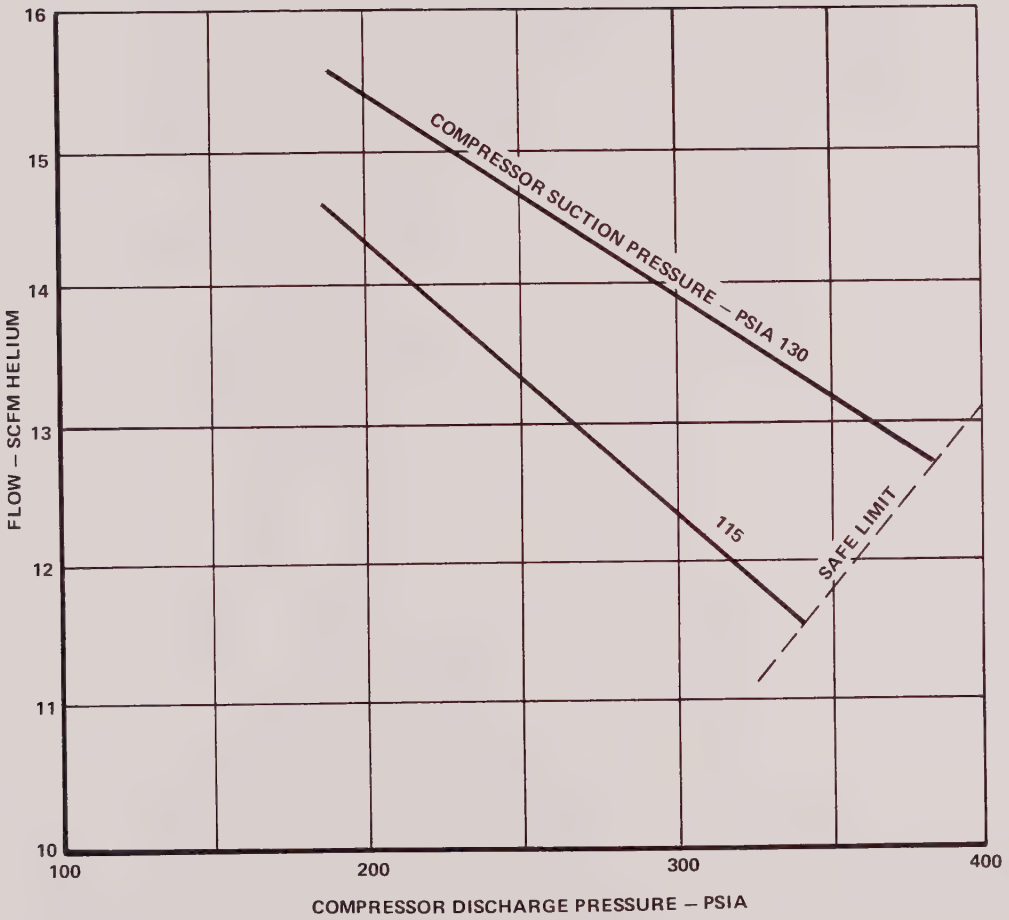


Figure 2-1 Compressor Flow Characteristics

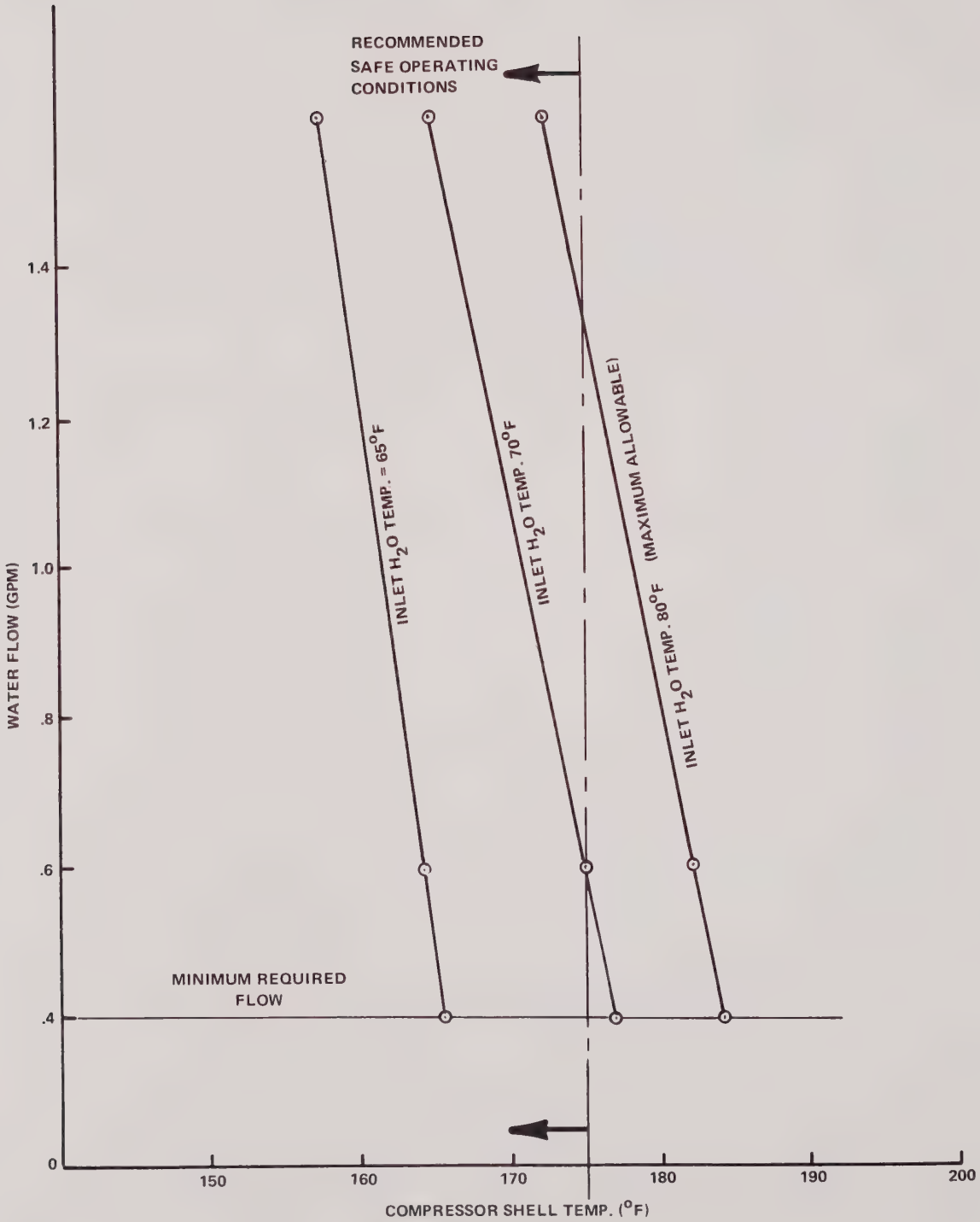


Figure 2-2 Cooling Water Requirements

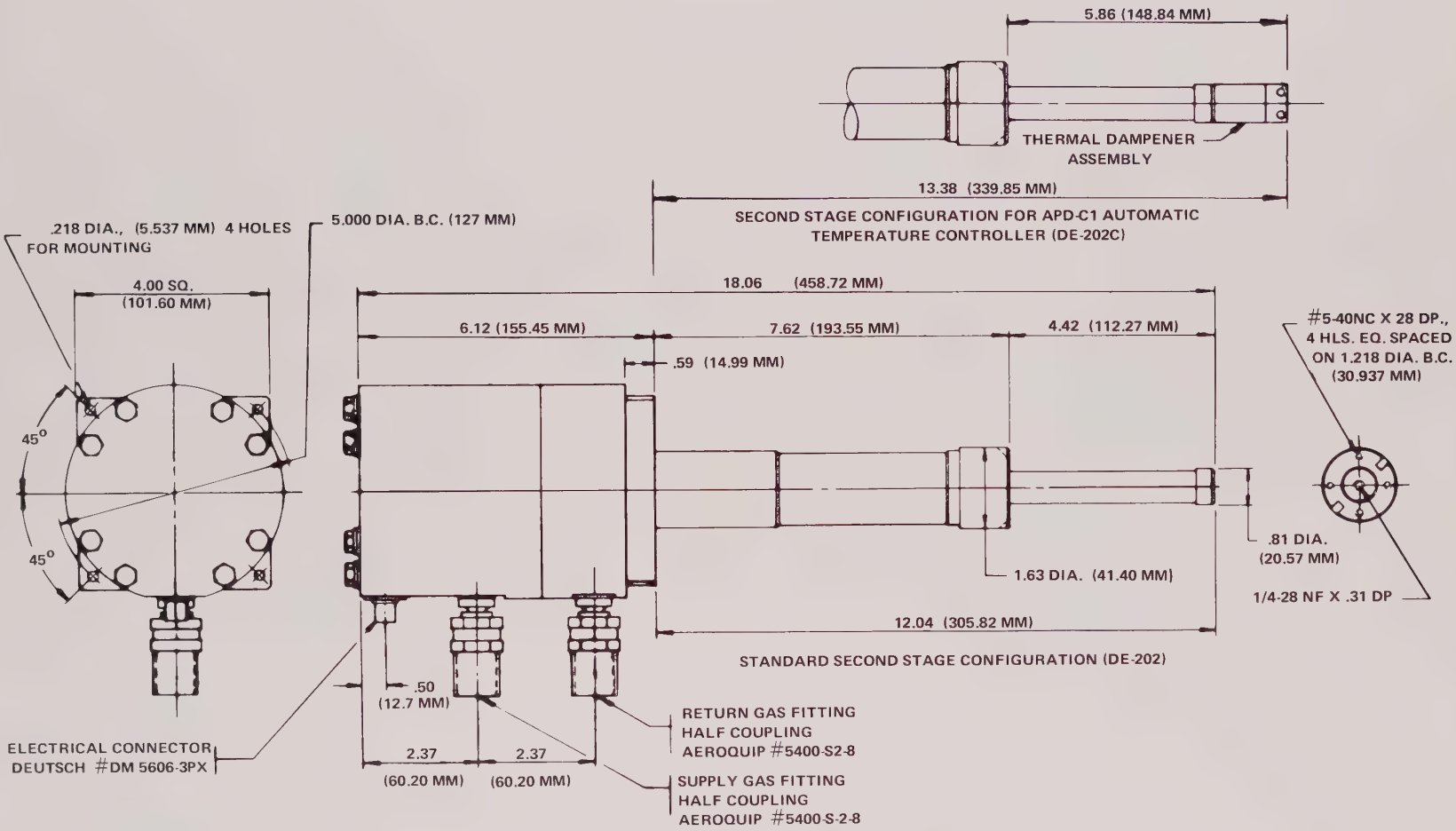

5.86 (148.84 MM)
THERMAL DAMPENER ASSEMBLY
13.38 (339.85 MM)
SECOND STAGE CONFIGURATION FOR APD-C1 AUTOMATIC TEMPERATURE CONTROLLER (DE-202C)
.218 DIA., (5.537 MM) 4 HOLES FOR MOUNTING
5.000 DIA. B.C. (127 MM)
4.00 SQ. (101.60 MM)
18.06 (458.72 MM)
6.12 (155.45 MM)
7.62 (193.55 MM)
4.42 (112.27 MM)
.59 (14.99 MM)
#5-40NC X 28 DP., 4 HLS. EQ. SPACED ON 1.218 DIA. B.C. (30.937 MM)
45°
45°
.81 DIA. (20.57 MM)
1.63 DIA. (41.40 MM)
1/4-28 NF X .31 DP
12.04 (305.82 MM)
STANDARD SECOND STAGE CONFIGURATION (DE-202)
.50 (12.7 MM)
RETURN GAS FITTING HALF COUPLING AEROQUIP #5400-S2-8
ELECTRICAL CONNECTOR DEUTSCH #DM 5606-3PX
2.37 (60.20 MM)
2.37 (60.20 MM)
SUPPLY GAS FITTING HALF COUPLING AEROQUIP #5400-S-2-8

Figure 2-3 Basic Dimensions Of DE-202 Expander Module

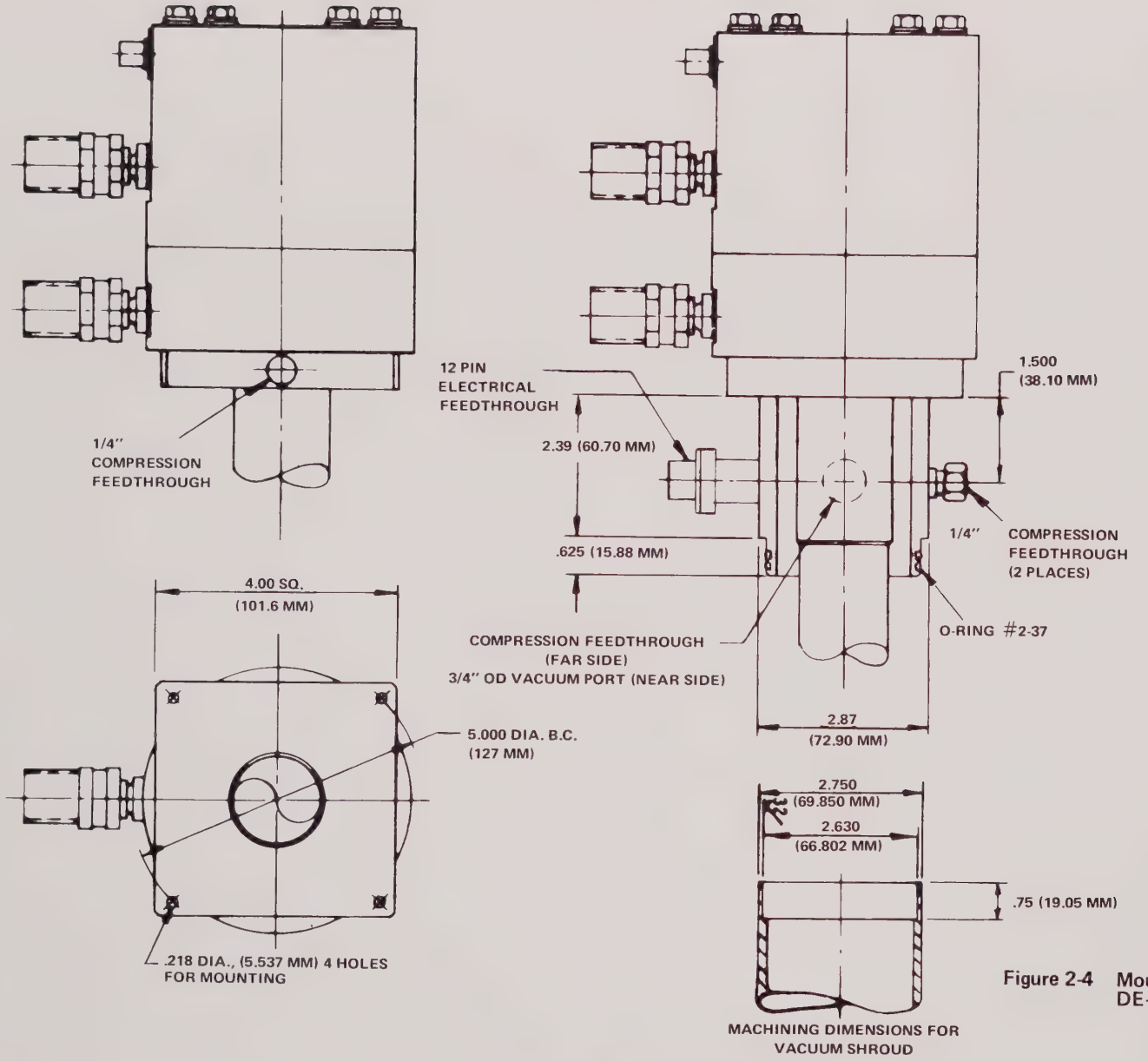
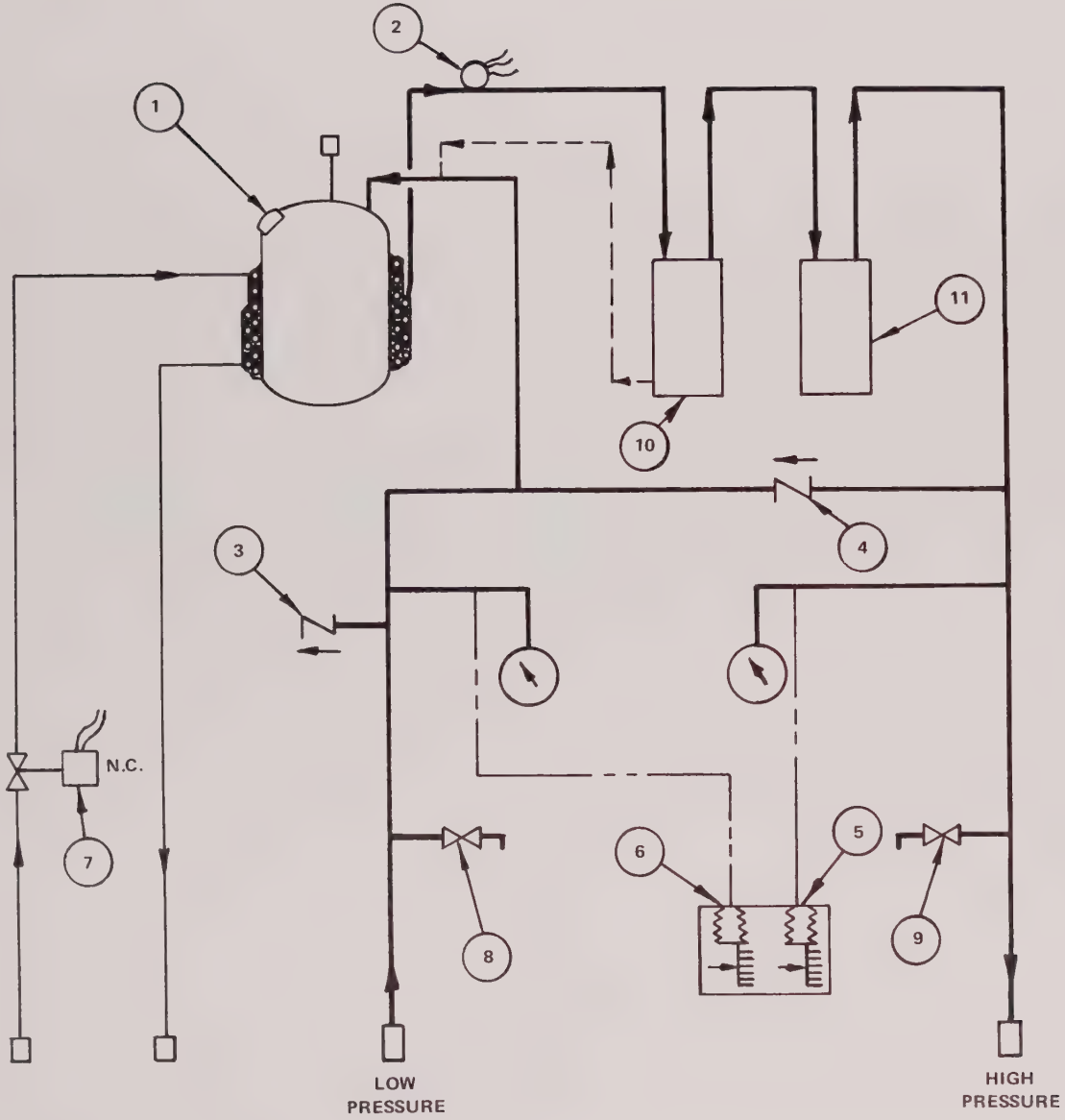


Figure 2-4 Mounting Arrangement For DE-202 Expander Module



HELIUM LINE

WATER LINE

OIL CAPILLARY

INSTRUMENTATION

1. COMPRESSOR OVERLOAD PROTECTOR
2. HIGH DISCHARGE TEMPERATURE SWITCH
3. ATMOSPHERIC RELIEF VALVE
4. IN-LINE RELIEF VALVE
5. HIGH PRESSURE SHUTDOWN SWITCH
6. LOW PRESSURE SHUTDOWN SWITCH
7. INLET WATER SOLENOID VALVE
8. CHARGE VALVE
9. VENT VALVE
10. OIL SEPARATOR
11. ADSORBER

Figure 2-5 Compressor Flow and Instrumentation Schematic - Water Cooled Compressor

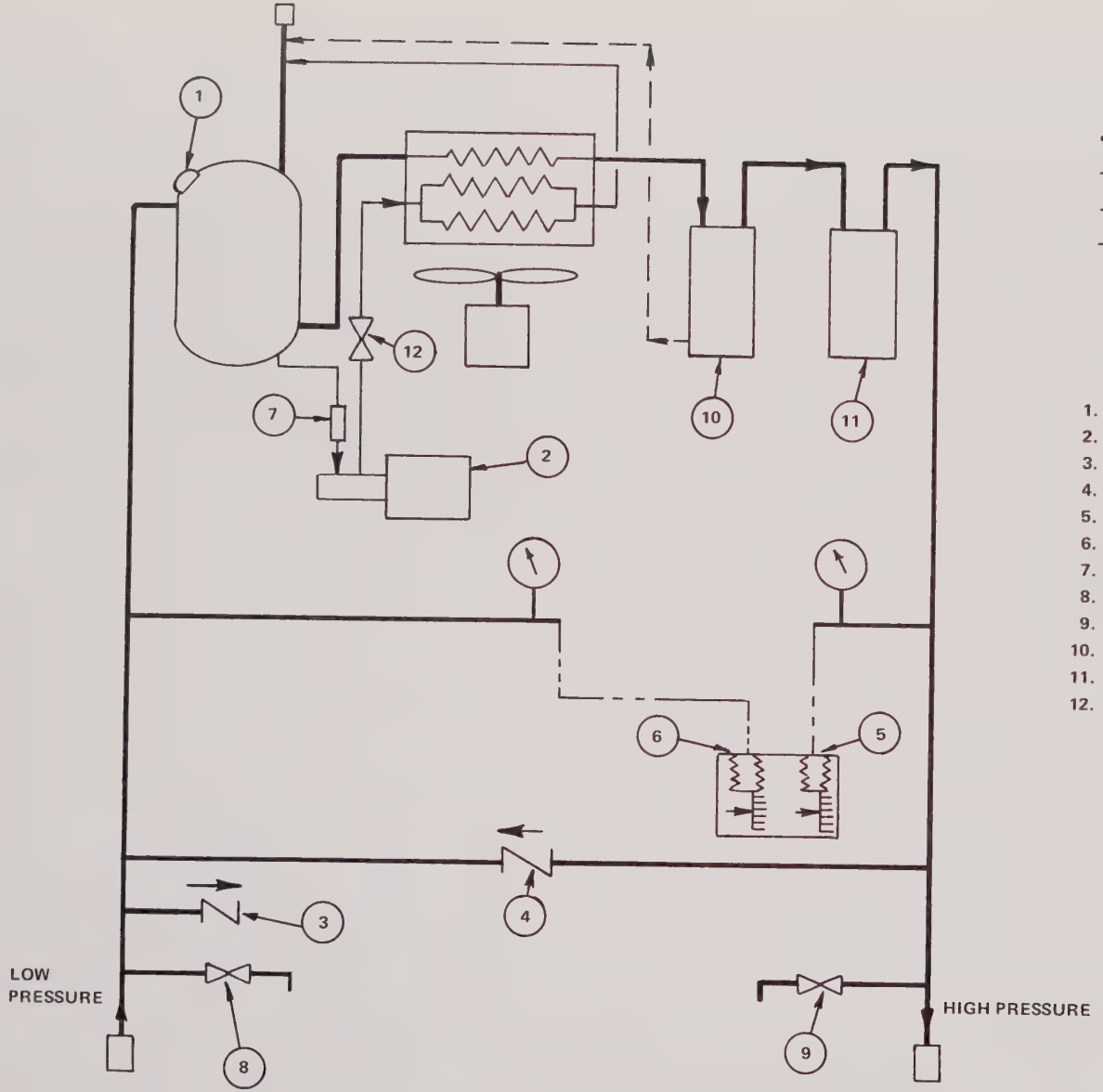


Figure 2-6 Compressor Flow and Instrumentation Schematic — Air Cooled Compressor

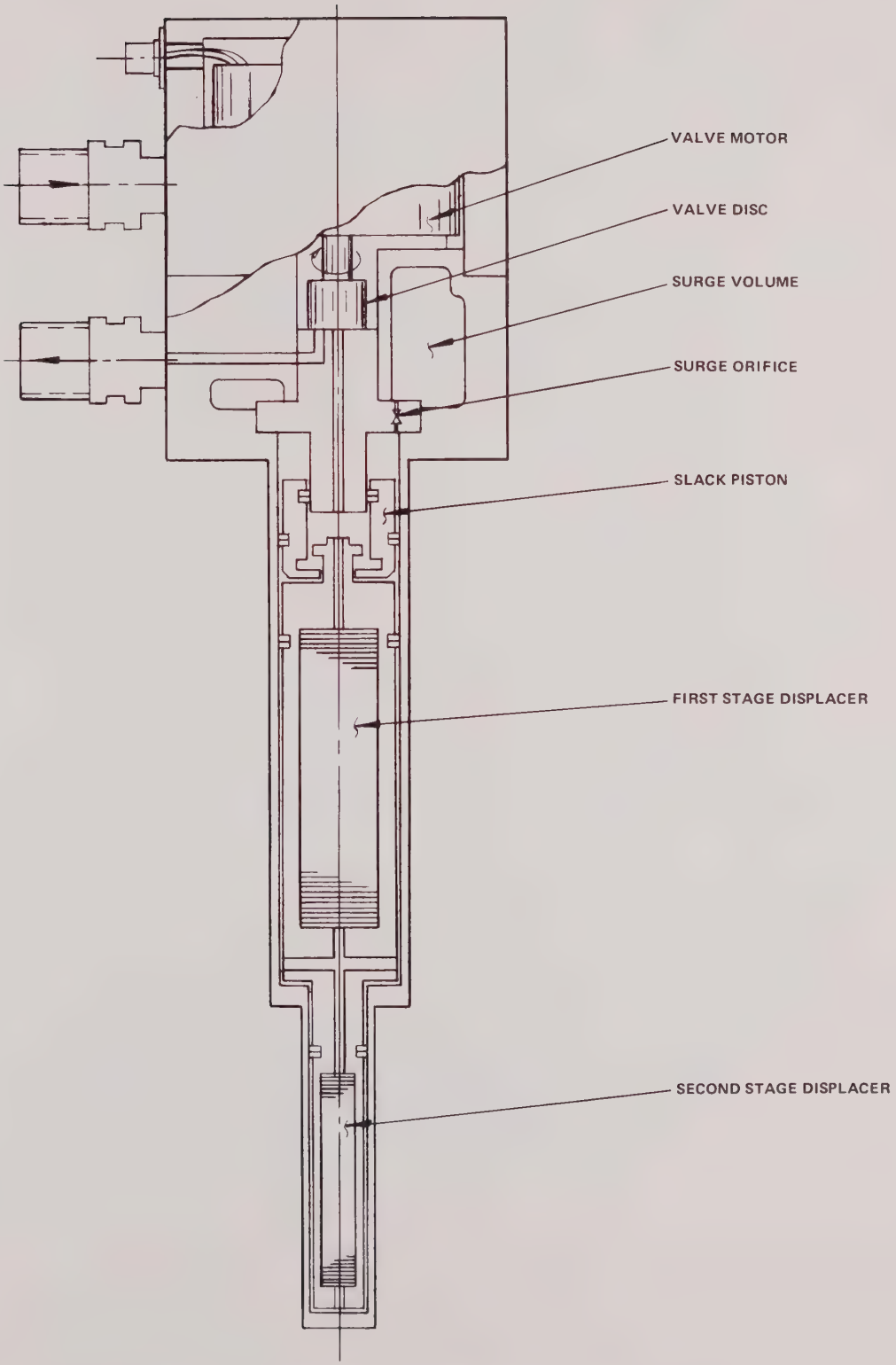


Figure 2-7 Expander Module Operational Schematic DE-202

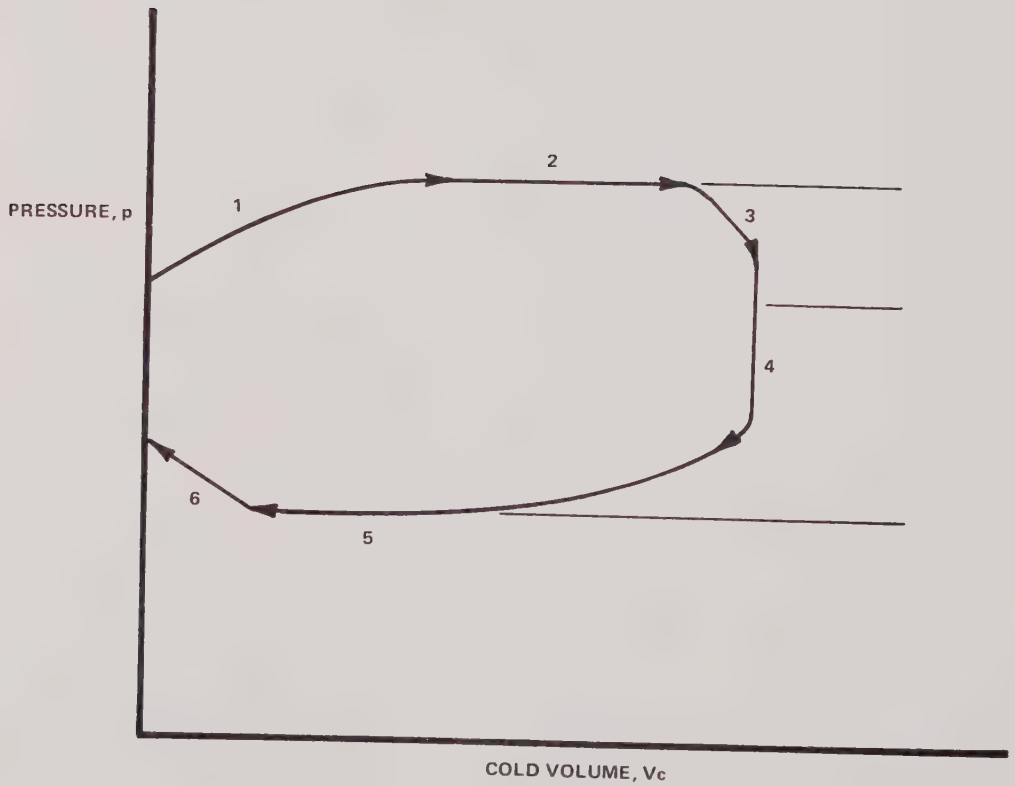


Figure 2-8 Cycle Diagram — Pressure vs Cold End Displaced Volume

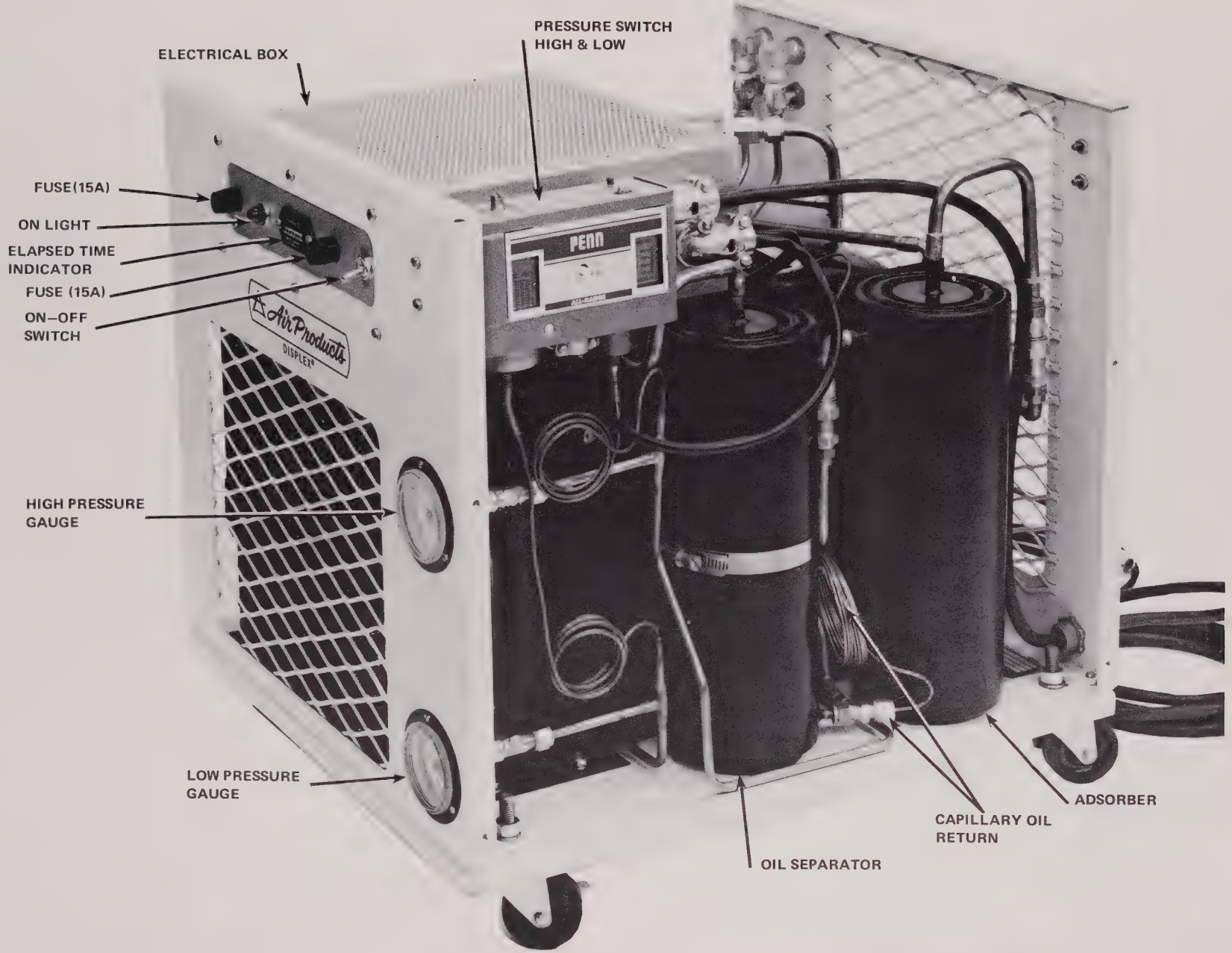


Figure 2-9 Air Cooled Compressor Module (Right Hand View)

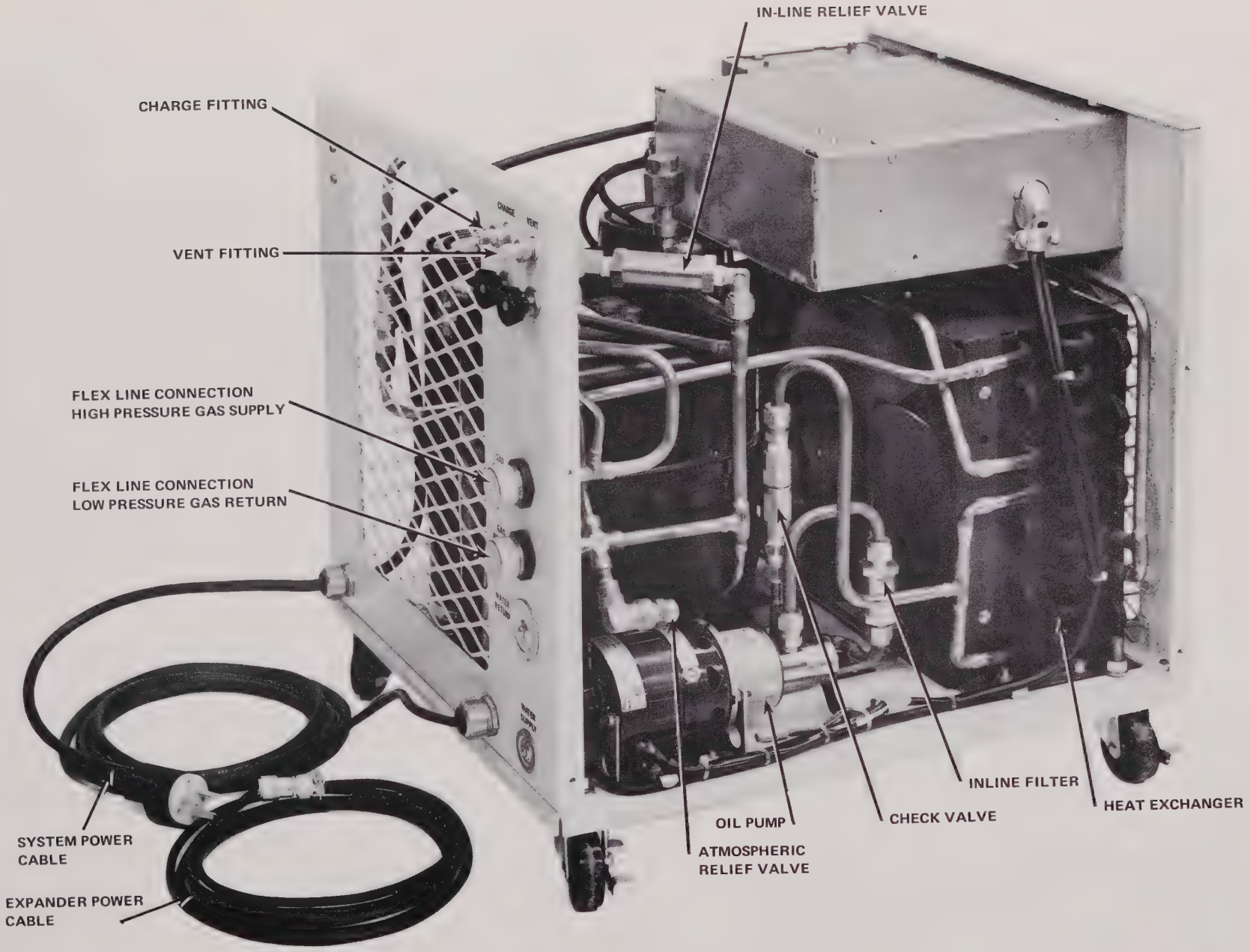


Figure 2-10 Air Cooled Compressor Module (Left Hand View)

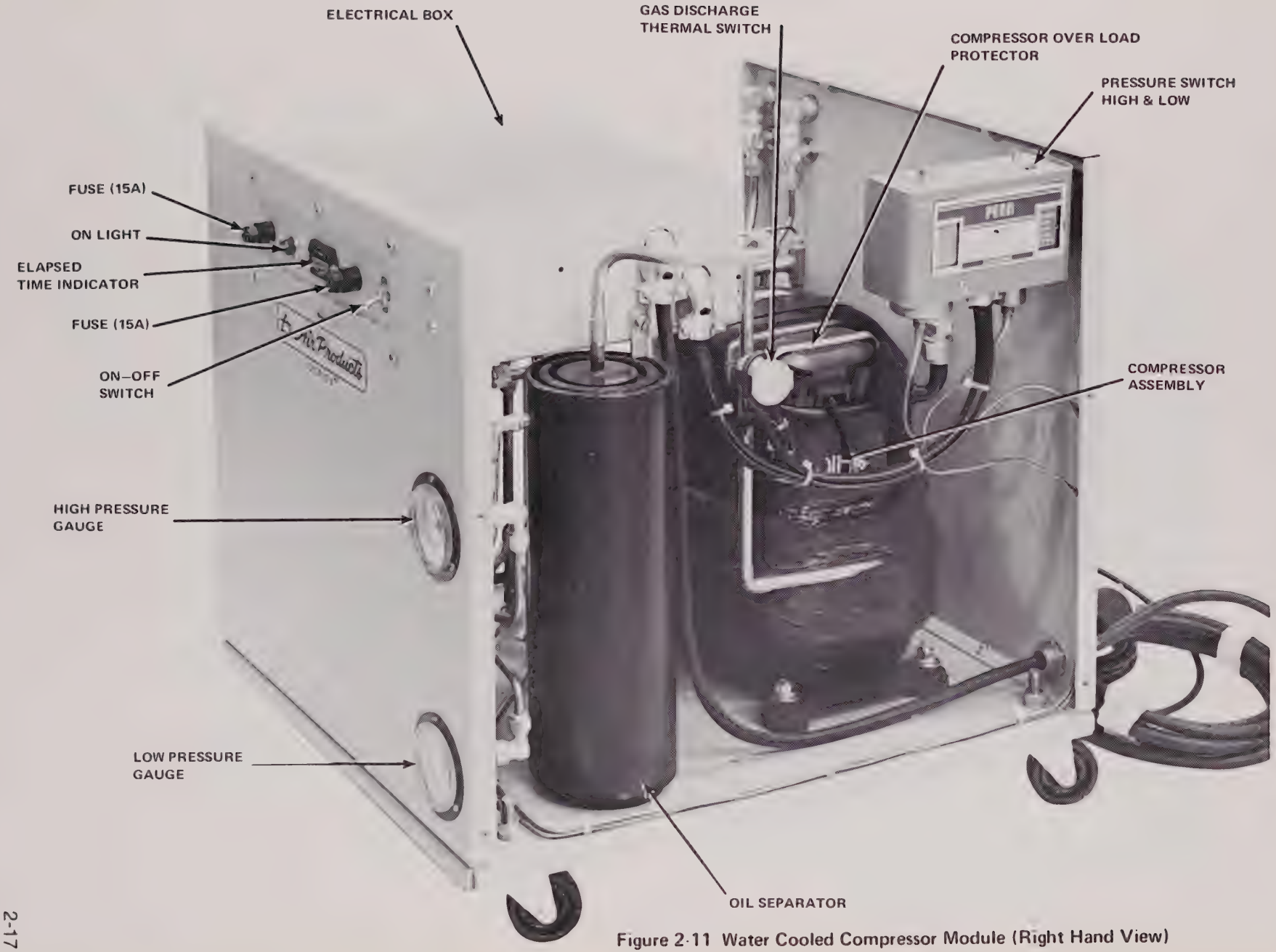


Figure 2-11 Water Cooled Compressor Module (Right Hand View)

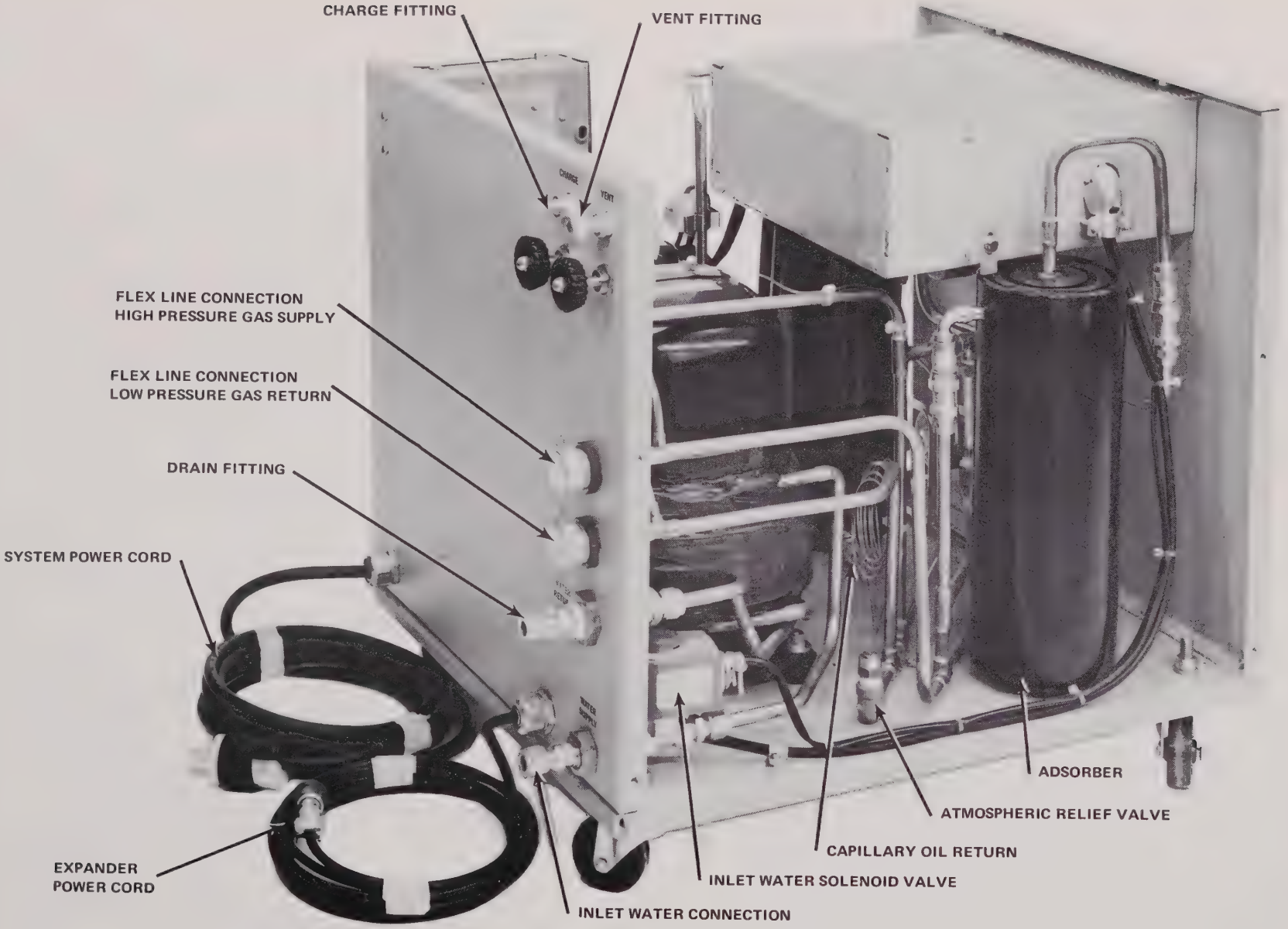


Figure 2-12 Water Cooled Compressor Module (Left Hand View)

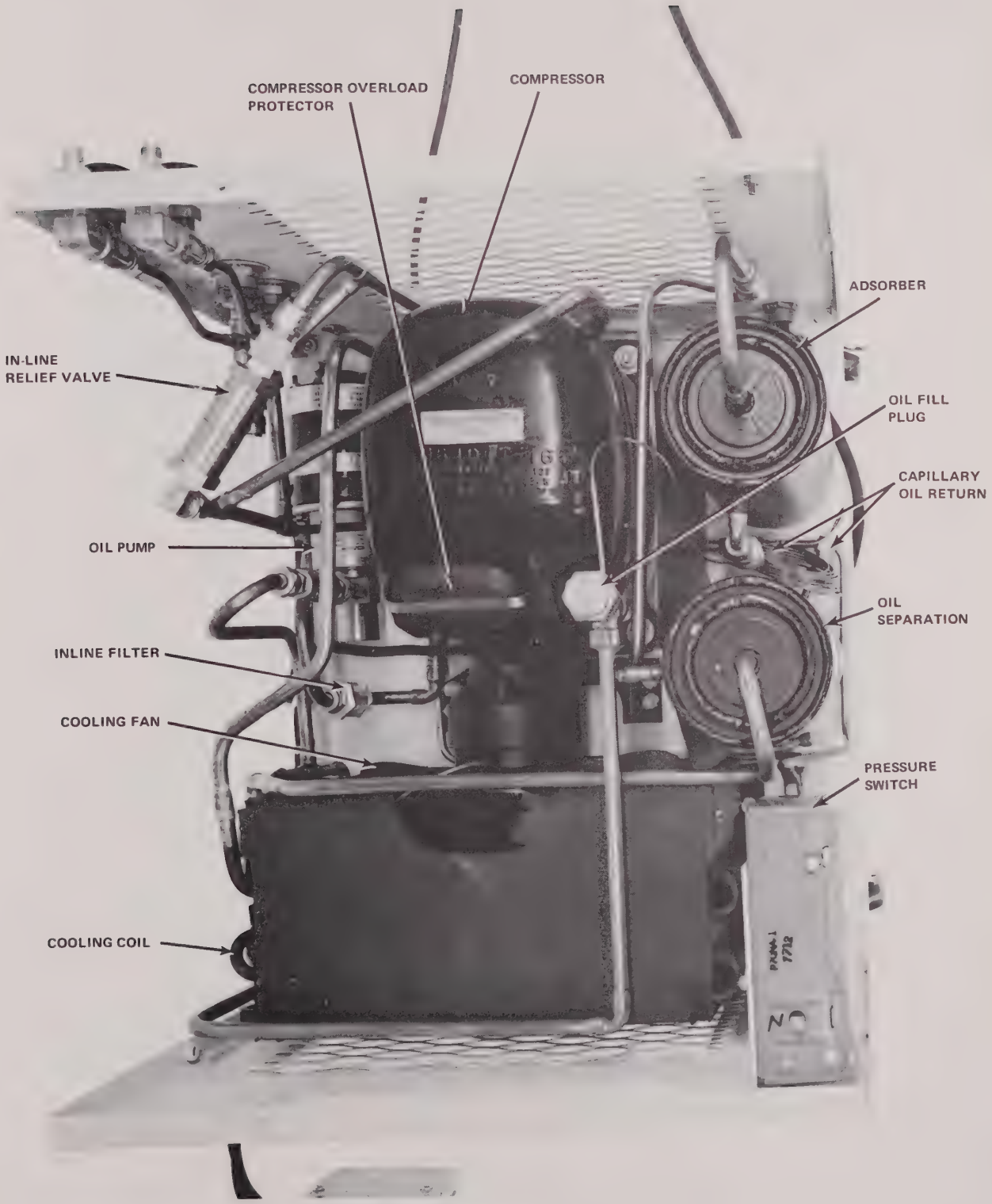


Figure 2-13 Air Cooled Compressor Module (Plan View)

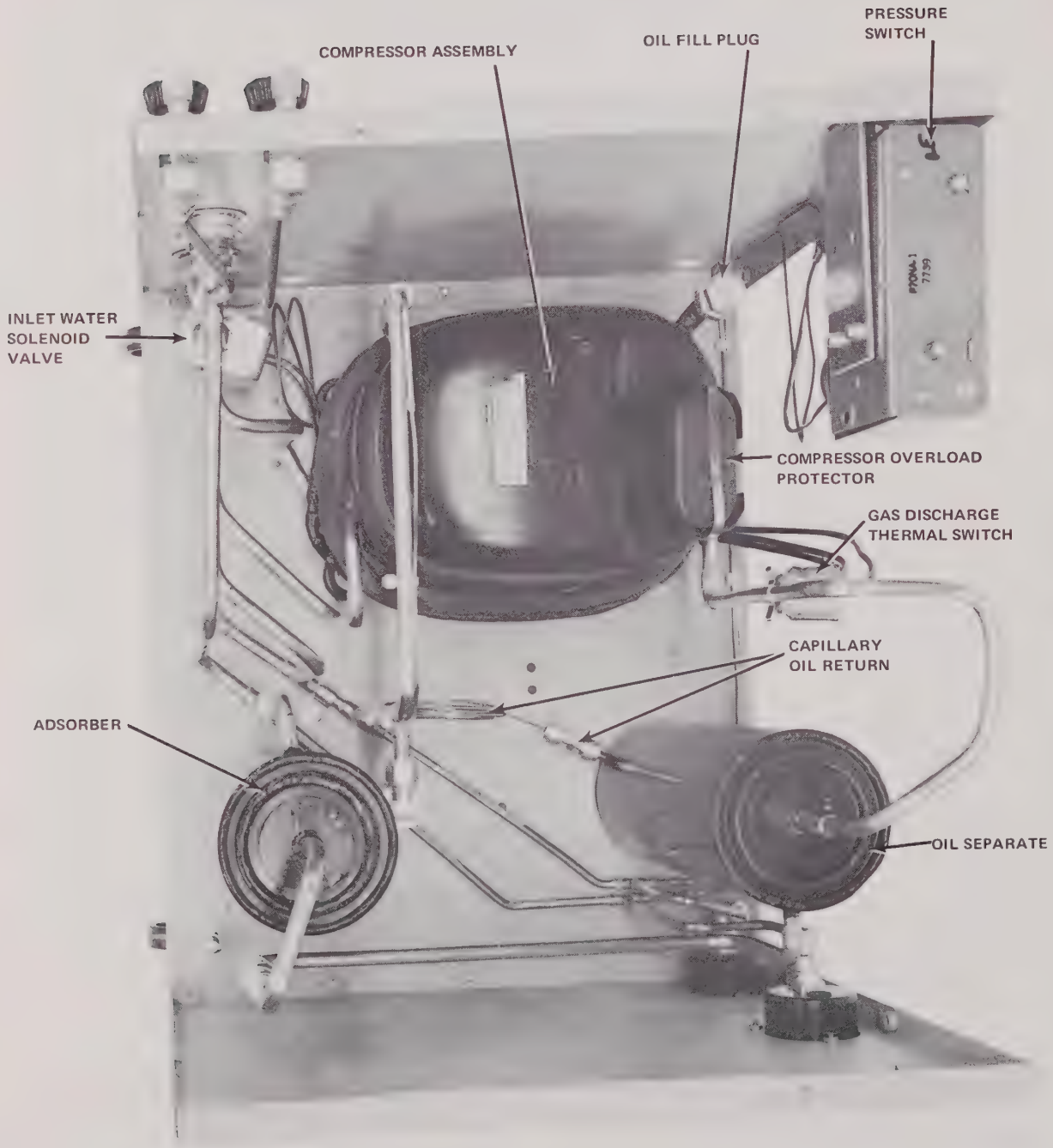


Figure 2-14 Water Cooled Compressor Module (Plan View)

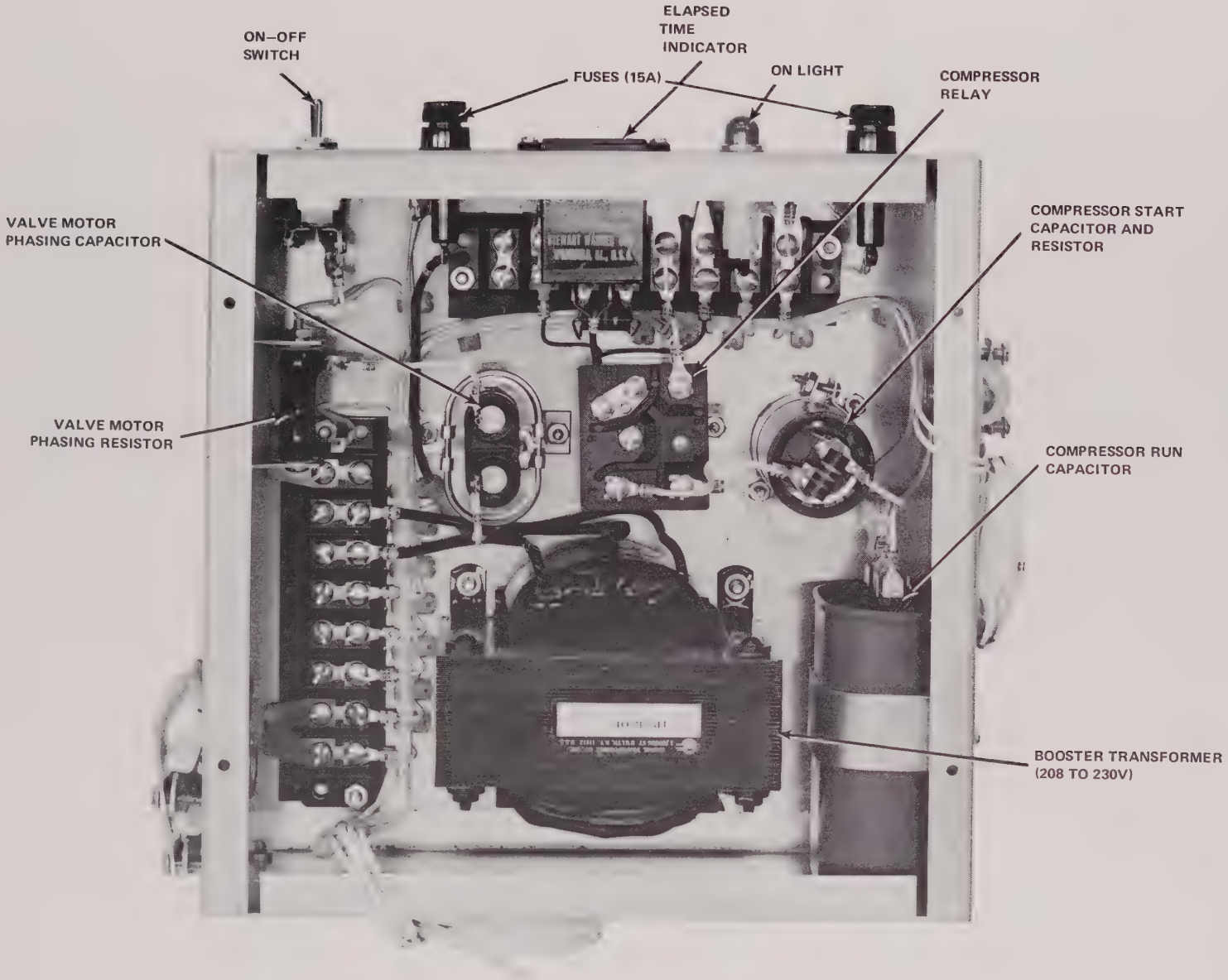


Figure 2-15 Electrical Box

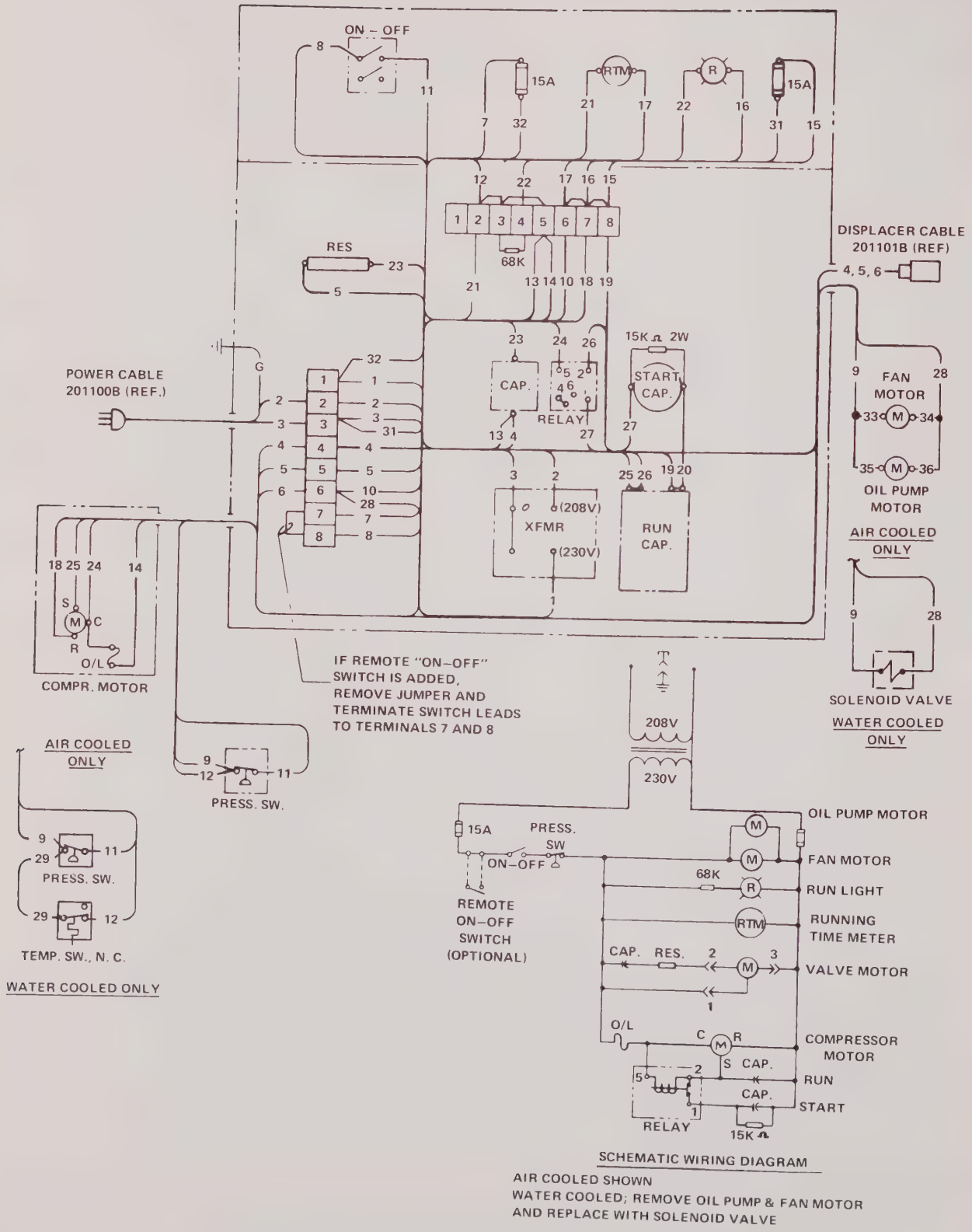


Figure 2-16 Schematic Wiring Diagram-Air and Water Cooled Compressor Module

SECTION 3
INSPECTION AND INSTALLATION

The following section describes the inspection, initial installation, and setup of the cryogenic refrigeration system. The procedures are outlined for the general situation. Individual interface considerations may change these procedures slightly.

3.1 COMPRESSOR MODULE

This section describes inspection and initial installation of the compressor module. Included are discussions pertaining to both the air- and water-cooled units. The singular difference between these two types of units is the cooling water requirement.

The compressor module is packed in a cardboard shipping box along with the expander and interconnecting lines. If it is a water-cooled unit, the water in the cooling circuit was removed prior to shipment.

After removing the compressor from the shipping container, remove the cover and perform the following pre-startup check list. This will insure proper operation of the compressor and eliminate possible contamination of the expander and interconnecting lines.

CAUTION

Be sure the unit is off and power is not connected whenever cover is removed.

3.1.1 Pre-Startup Check List — General Notes. It is advisable to install the compressor at a height where the gauges are convenient to read and the gas and water connections are easily reached. The compressor must be operated in a level, upright condition.

CAUTION

In the event the compressor was not received in an upright position, it is good practice to operate the compressor separate from the displacer for one half hour to ensure proper oil distribution.

The compressor system is designed for general use in a laboratory environment. The ambient temperature in the area of the compressor package must be between 40 and 100°F. A higher local temperature will cause overheating and shutdown of the compressor. A lower local temperature may cause startup problem due to increased load associated with a higher oil viscosity.

The compressor cover must be securely fastened before the power is connected and the unit is turned on. The cover serves to protect the user from hot gas lines and absorbs some of the sound. On air-cooled units it also protects the user from contact with the fan blade and directs the cooling air over the compressor. The air-cooled compressor needs to have clearance in the front and back for air circulation. Avoid a location where dirt will be drawn into the unit.

After placing the compressor in its permanent location, convenient to the necessary utilities, the next step is to connect the necessary service lines. Figure 3-1 shows the service connections on the rear of a water-cooled unit. Check the readings on the pressure gauges. They should both read 215 psig $\mp$ 5 psig.

If equalization pressure is below 200 psig, but above 10 psig, recharge system to 215 psig

and leak check system. If gas pressure is less than 10 psig, recharging and cleanup is required. Refer to section 3-4.

CAUTION

If gas is added on a continuous basis due to helium leaks, the residual impurities collect in the adsorber and displacer. This condition will lead to a malfunction.

Leak check the system with a helium mass spectrometer leak detector. If this is not available, use soap solution to locate leak. Please note that soap solution leak checking techniques require more care than when using the leak detector. It is Air Products' experience that leaks detectable by sniffing with a leak detector are also detectable with soap solution if sufficient observation and time is allowed for bubbles to form. Rinse away soap residue to avoid possible corrosion.

Starting at the gas return fitting at the rear of the compressor, check each joint in the gas lines. Leaks may occur at the compression or pipe fittings. Also check the system packing on the charge and vent valves.

If a leak is found around a compression fitting, simply tighten with the proper wrench. If this is ineffective, remove nut, install one wrap of teflon tape over ferrule and reinstall.

If leak is found around pipe tread, vent all gas from system, and break necessary compression fitting to allow for removal. Install new Teflon tape and reinstall fitting.

It is very unlikely that a leak would develop at a braze joint; however, if this should occur, notify Air Products and Chemicals, Inc. for special instructions.

The necessary tubing for connecting the inlet water line and drain on the water cooled compressor are supplied with the owner's installation kit. Connect the ⅜" OD polyethylene tubing to the water supply and water return fitting.

On the inlet side, allow full water line pressure to be applied to the compressor inlet fitting. The system is equipped with a solenoid valve which is normally closed and opens when the compressor is started. Do not restrict the inlet water flow. If there is a hand valve in the inlet line, it can be left in the open position permanently. Line water pressure must be at least 20 psig and not greater than 150 psig. A differential water pressure between the water supply and water return must be 20 psig to provide a flow of .6 gpm. Inlet water temperature must not exceed 80°F.

CAUTION

A water temperature greater than 80°F will result in insufficient cooling of the compressor and potential ***failure****.*

The power requirement of the single phase compressor is 230V ∓ 5% 60 Hz or 208V ∓ 5% 50 Hz. The input power cord is equipped with a 3-point plug (Hubbell No. 5666-C). It may be necessary to replace this plug with one suitable for the available receptacle. It is recommended that the line voltage in the customer's installation be measured prior to operating the compressor.

WARNING

Only qualified electricians should make voltage measurements at the receptacle.

CAUTION

Incorrect power supply to the compressor will lead to compressor ***failure****.*

The supply voltage should be measured at customer receptacle and it must agree with voltage requirements stated on a tag attached to each compressor. All systems are equipped with a 208/230V transformer. On units shipped domestically this is connected to boost the more common 208V to 230V.

On export units where 50 Hz power is available the transformer is connected in reverse to drop the more common 230V to 208V.

Table 3-1 summarizes the various power situations likely to be encountered. Refer to this Table if your particular situation is other than the specified limits outlined above. Figure 2-16 gives further reference for Table 3-1. The table illustrates one segment of Figure 2-16.

Operate compressor separate from the displacer for one-half to one hour. Record equalization pressures, then start compressor. Pressure readings should be 325 ∓ 5 psig high pressure, 100 psig low pressure. Check water flow , flow rate should be 0.4 gpm minimum. Check the pressure differential between the high and low pressure gauges. This should be 230 psig ∓ 5 psig. Shut down compressor watching pressure decay time. The pressure should decay to 250 psig in less than 90 seconds if the oil return capillary flow is normal.

The second power cord shown in Figure 3-1 is the supply cord for the expander module. This plugs into the valve motor housing on the top of the expander. Plug is properly installed when orange ring is visible.

3.2 FLEXIBLE INTERCONNECTING GAS LINES.

The system is equipped with flexible, interconnecting gas lines. These serve to supply high-pressure gas to the expander from the compressor and to return low-pressure gas to the compressor. These lines are precharged and shipped disconnected from the system. They are equipped with self-sealing fittings on both ends. After the compressor is installed, remove the dust caps and connect the two gas lines to the compressor module.

WARNING

The male and female coupling halves must never be unscrewed from their corresponding adapter fitting without first depressurizing the component to which each is attached.

CAUTION

Do not disconnect gas lines from the expander when it is cold or before the pressures have equalized.

CAUTION

Avoid twisting of the flex lines.

To "make" the coupling, thread the union nut until metal to metal contact is made. The gas line begins to open at this point and is fully open after an additional 2½ turns. The required torque is about 35 ft. lbs.

When connecting or disconnecting the self-sealing couplings, wrenches should be held on the male or line coupling while the union nut is being turned. On the expander the

line coupling should be held during the making of the fittings, and the male coupling during the breaking. This will avoid twisting of the flex lines and loosening of the coupling half from the adapter fitting. Loosening of the bulb head fitting on the compressor should also be avoided. Figures 3-2 and 3-7 demonstrate these techniques. The necessary wrenches are included with the installation nut.

After connecting the lines, the system pressure should be checked to see that the gas lines and expander have retained their charge in shipment. The pressure should be 215 $\mp$ 5 psig. Before connecting lines, always be sure that any visible particles are wiped off the couplings before the two halves are mated. Also check to see that the gasket in the male half of the coupling is in place so it won't be pinched when the connection is made. This gasket has a light coating of vacuum grease. A thin film of vacuum grease on the gasket and on the threads reduces the torque required to connect the couplings.

NOTE

Pinching of the seal is a common cause of gas leakage from the system. Proper location of the gasket and a light coating of vacuum grease effectively avoids this problem.

The lines are color-coded and it is essential to connect each line to the proper fitting.

NOTE

Connect the red-marked (high pressure) line to the "Gas Supply" fitting on the back of the compressor (Figures 2-10 and 2-12). Connect the green-marked (low pressure) line to the "Gas Return" fitting.

Failure to connect the lines properly will result in abnormal functioning of the expander, although no damage will result. Both ends are identical and either end can be connected to the compressor.

3.3 EXPANDER MODULE

The expander module, when supplied with gas and electrical power from the compressor and when insulated properly, serves as a source of cryogenic refrigeration. There are many different arrangements for interface equipment at the cold end which may be supplied with the expander depending on the customer's individual experiments or objectives. There are also several variations of expander flanges.

Figures 3-3, 3-4, 3-5 illustrate three variations of the DE-202 expander module. The internal mechanisms are identical. The differences are in the instrumentation and interface arrangements. Figure 3-3 illustrates the basic unit without instrumentation and a vacuum feed through skirt.

To achieve minimum temperature capability of the system, it is necessary to insulate the expander from ambient conditions. The two main sources of heat load are conduction from any surrounding medium and ambient temperature radiation. To reduce radiation, most CS-202 systems are equipped with a nickel-plated copper radiation shield. This mounts on the first stage, operates at 40-60°K and shields the second stage using available first stage refrigeration. The advantage of this arrangement is that now the second stage must only look at a 40-60°K source instead of 300°K and radiation heat transfer is proportional to T^4 (T = absolute temperature). If the system does not include a radiation shield, it may be helpful to wrap the second stage with aluminized mylar or superinsulation if the ex-

periment warrants it. In cryopumping applications this is not required.

The necessity of providing good vacuum insulation is important in all situations. Figure 3-6 shows the variation of apparent thermal conductivity with residual gas pressure for a typical multilayer insulation. This apparent "conductivity" includes radiation heat transfer, gas conduction and solid conduction effects. Of significance is the sharp decrease in thermal conductivity between 10 torr and 10^{-3} torr. When no multilayer insulation is used, as in most Displex systems, a vacuum of 5×10^{-3} torr or better is required to achieve good performance. Use of a well-trapped oil diffusion pump is the best method of achieving this; however, it is adequate in most cases to use a two-stage mechanical roughing pump which is trapped with a molecular sieve trap to evacuate to 5×10^{-3} torr. As soon as the refrigerator is operating below 20°K the vacuum pump should be valved off. The expander will pump itself down to a harder vacuum.

NOTE

Connection of any vacuum pump with the expander vacuum space will result in a migration of contaminants to the cold end of the refrigerator over a period of time.

When warming a system the reverse procedure is followed. First be sure the vacuum pump is operating at minimum pressure; second, open the valve; and third, immediately shut off the refrigerator. If the vacuum pump "gurgles" during warmup for a period of about 30 seconds, when the expander is at 40°K, then the vacuum system has a leak which should be fixed.

The double O-ring seal shown in Figures 3-4 and 3-5 are designed for use in high vacuum service. Use of a light coat of high quality vacuum grease on these rings is recommended. A container of grease is provided in the installation kit. Any Air Products vacuum shroud used on the double O-rings is rotatable, if required, while under vacuum.

The gas connections at the expander module have self-sealing quick disconnect couplings identical to those located on the compressor. Proper position for the wrenches is shown in Figure 3-7.

CAUTION

The hose connections are color-coded. Make certain the red-marked (high pressure) connections are matched, and the green-marked (low pressure) connections are matched.

Repeated usage of the fittings may cause some galling of the threads on the fittings. To minimize this wear, apply a small amount of vacuum grease or UCON-LB-300X oil to the threads.

3.4 GAS CLEANUP PROCEDURES

The complete Displex cryogenic system is shipped in a fully charged condition. It should not be necessary to charge, purge, or clean up the helium gas in the system; however, since there may be situations arising from maintenance or service requirements where charging and cleanup will be necessary, it is important that the user be familiar with the general procedures. The following section covers these procedures in detail. It is best to clean up the two basic modules separately, that is, the compressor independently from the expander.

WARNING

Do not transfer cylinder helium to the refrigeration system without the use of a pressure regulator.

3.4.1 Compressor-Module. The following steps should be followed when charging and cleaning up the compressor. It is helpful to refer to the flow schematic for the compressor module, Figures 2-5 and 2-6 when going through the following procedure.

a. Disconnect the interconnecting gas lines at the expander module (Reference Figure 3-7).

b. Connect a source of compressed helium gas to the charge fitting on the back of the compressor. The fitting is a ¼" Gyrolok. The source of helium should be a high purity grade, 99.95% purity, or better and a dew point of less then -80°F.

c. Charge the system to 100 psig slowly.

d. Close the charge valve and open the vent valve. Slowly vent the entire charge.

e. Repeat steps 3 and 4 above a total of five times.

f. After the last vent, charge the system slowly to 215 psig.

g. Start the compressor with the helium supply lines still connected to the charge fitting. Leave the charge valve closed. After the unit is running, crack the vent valve slightly to vent a small flow of gas. Then open the charge valve to make up the vent flow. When doing this, set the pressure regulator on the helium source at the suction pressure which the compressor is holding. The vent flow during this period of open-cycle operation should be 0.1 to 0.2 scfm.

h. Continue the open-cycle running for 30 minutes. Shut down the compressor and close the charge and vent valves. Make sure that the system charge remains at 215 psig or slightly greater. Heating during operation will cause a rise in system pressure. This completes the cleanup procedure.

3.4.2 Expander-Module. The following procedure should be followed when charging and cleaning up the expander.

CAUTION

Do not try to clean up the expander by pulling a vacuum on it.

The valve motor will burn out if it is turned on while the expander is evacuated.

a. Disconnect the interconnecting gas lines at the expander. Leave the power cable to the expander plugged in.

b. Connect a source of compressed helium gas to the high-pressure self-sealing gas fitting. (upper of the two connections). A pressure regulator with a reasonably accurate gauge should be part of this supply. To do this, a mating Aeroquip fitting assembly is required. Two of these are supplied as part of the installation.

c. Connect the second mating Aeroquip fitting to the low-pressure fitting (lower of the two connections). This will become a vent to atmosphere during cleanup.

d. Charge the cold end to 100 psig and set the regulator on the gas supply at this pressure.

e. Start the compressor. This time gas will begin exhausting from the low pressure expander fitting.

f. Continue running in this manner for 4-5 seconds. This is referred to as "running open-cycle." With the power cord connected to the expander, the valve motor is turning and gas is being cycled through the expander and exhausted to the atmosphere; thus, a running purge is established which flushes out the contaminants.

g. After the 4-5-second running period, close the helium supply off at the cylinder (not the regulator) and allow the system to bleed down until the pressure in the system is slightly above atmospheric, 5-10 psig.

h. Open the gas supply. Repeat steps d to g for a total number of cycles equal to 6-8.

i. With the inlet pressure set at 100 psig, remove the low-pressure temporary fitting while the system is running.

j. With the low-pressure fitting removed, increase the regulator to 215 psig, turn off the compressor and close the gas supply at the cylinder valve.

k. Remove the high-pressure temporary fitting. This completes the cleanup and charge procedure.

3.4.3 Flexible Gas Line. The following procedure should be followed when charging and cleaning the flexible interconnecting lines. This procedure is to be used only when the flexible gas lines are clean and charged as a separate component. Causes for this can arise when quick disconnect fittings have to be replaced.

a. With interconnecting lines disconnected at both ends, install adapter fittings. Two of these are supplied as part of the installation kit.

b. Connect a source of compressed helium gas to one fitting. A pressure regulator with a reasonably accurate gauge should be part of this supply.

c. Set regulator at a pressure sufficient to purge at 0.1-0.2 scfm and allow lines to be purged for 15 to 30 minutes.

d. With purge still applied, remove adapter fitting which is being used as a vent.

e. Charge line to 215 psig.

f. Remove charge adapter fitting.

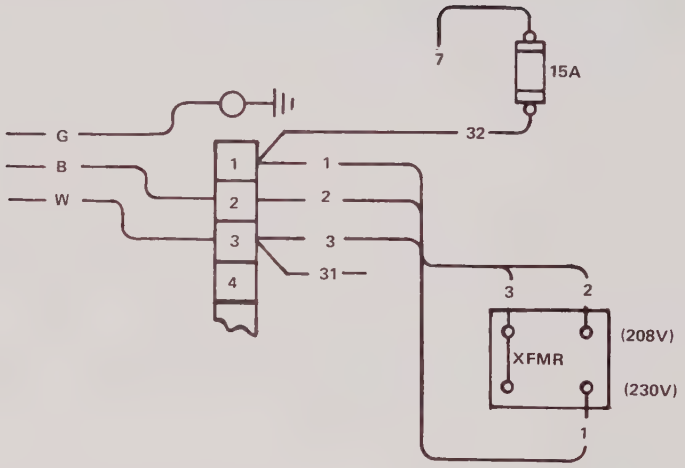
g. Repeat procedure for second interconnecting line.

Table 3-1
Wiring Schemes For Various Voltage Levels and Frequencies

TRANSFORMER USED TO STEP UP VOLTAGE FOR THE FOLLOWING CASE:

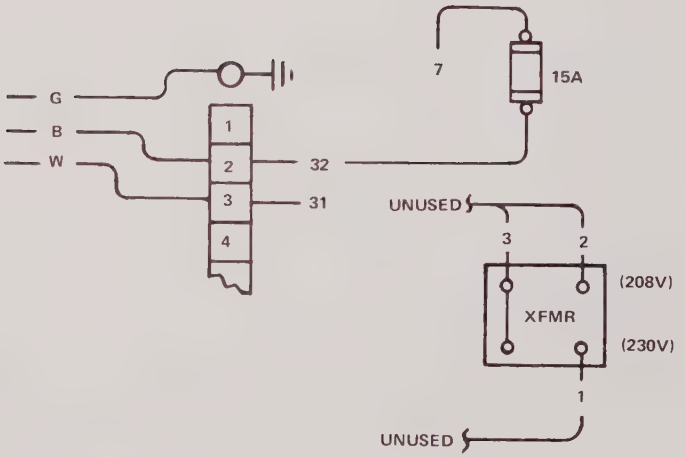
208 ±5% VAC, 60 Hz

ALL DOMESTIC U.S. SYSTEMS SHIPPED IN AN EQUIVALENT CONFIGURATION.



NO TRANSFORMER REQUIRED FOR FOLLOWING CASES:

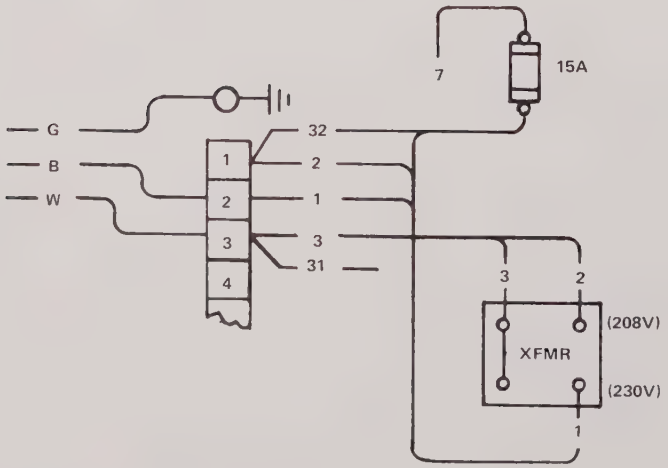
208 ±5% VAC 50 Hz
220 – 230 VAC, 60 Hz



TRANSFORMER USED TO STEP DOWN VOLTAGE FOR FOLLOWING CASE:

230 ±5% VAC, 50 Hz

ALL EXPORT SYSTEMS SHIPPED IN THIS CONFIGURATION.



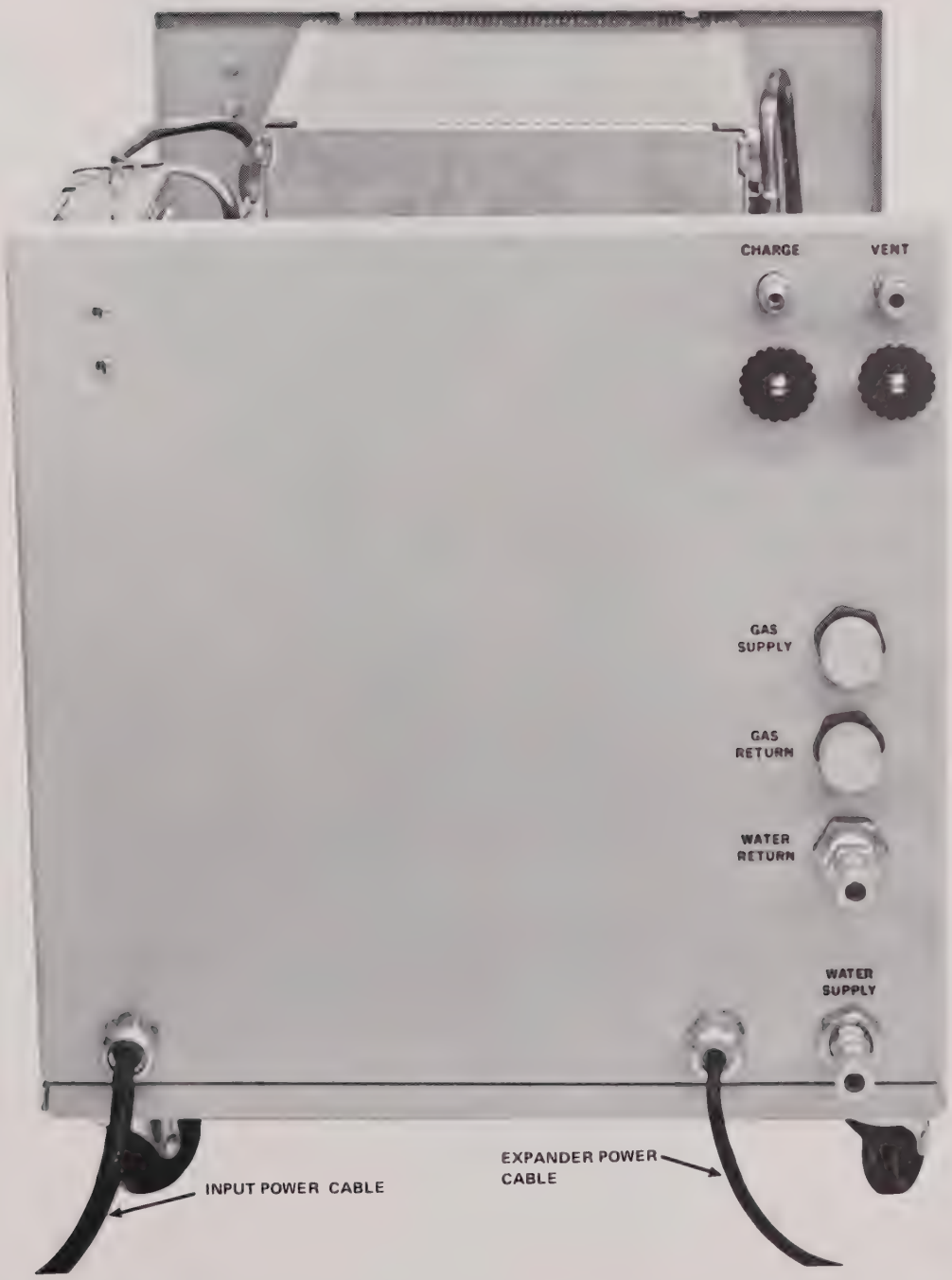


Figure 3-1 Service Connections for Water Cooled Compressor

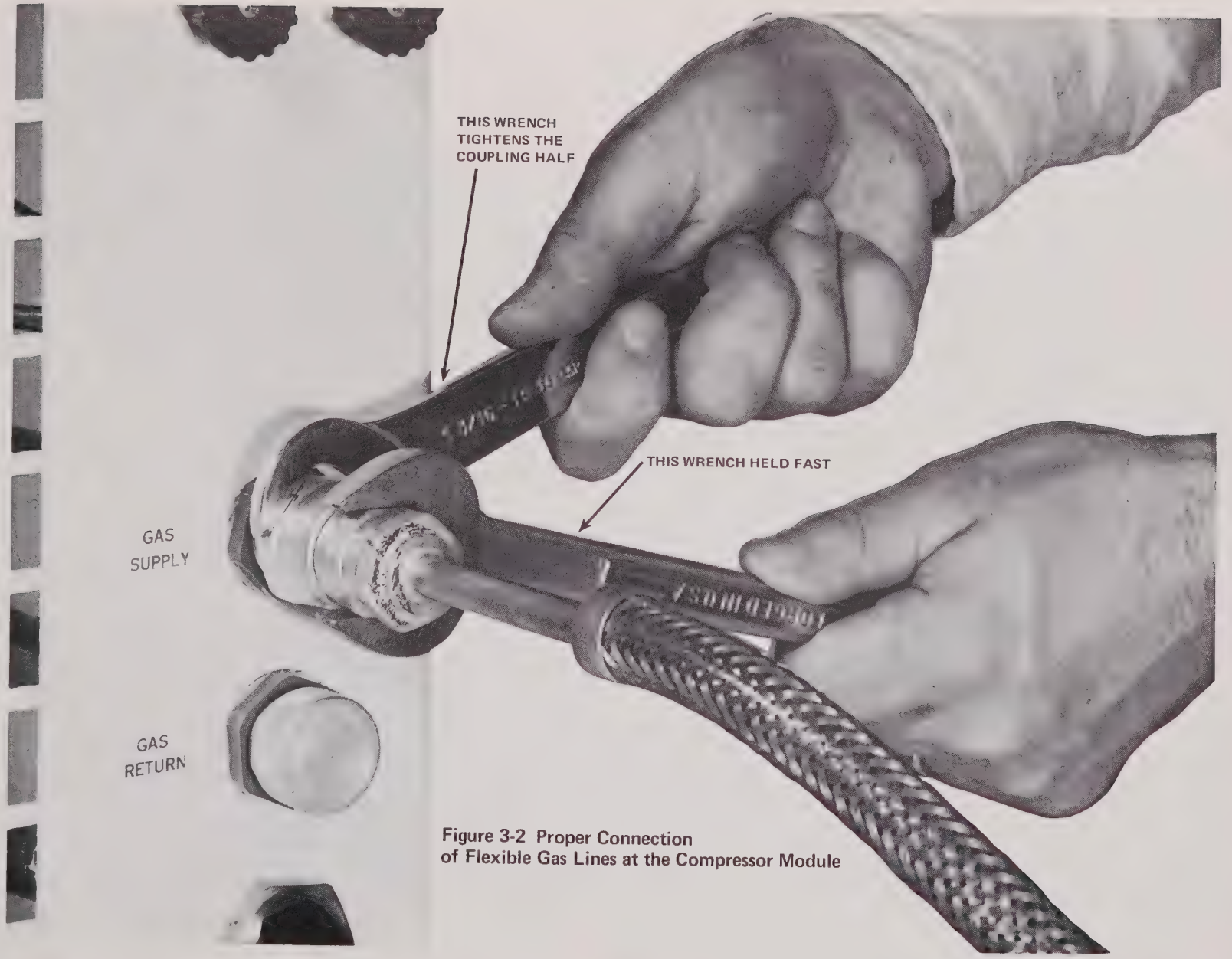


Figure 3-2 Proper Connection
of Flexible Gas Lines at the Compressor Module

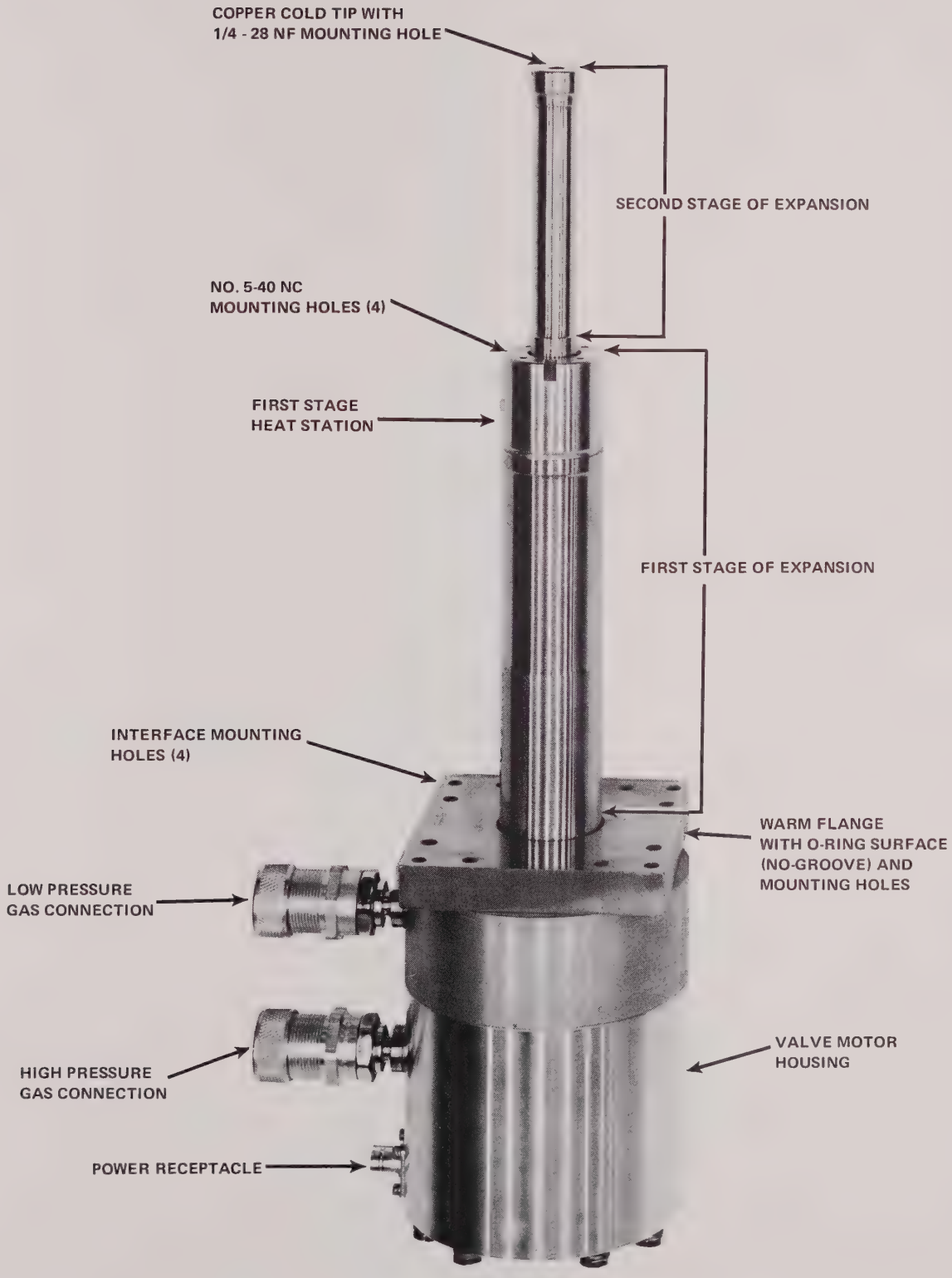


Figure 3-3 Basic DE-202 Expander Module

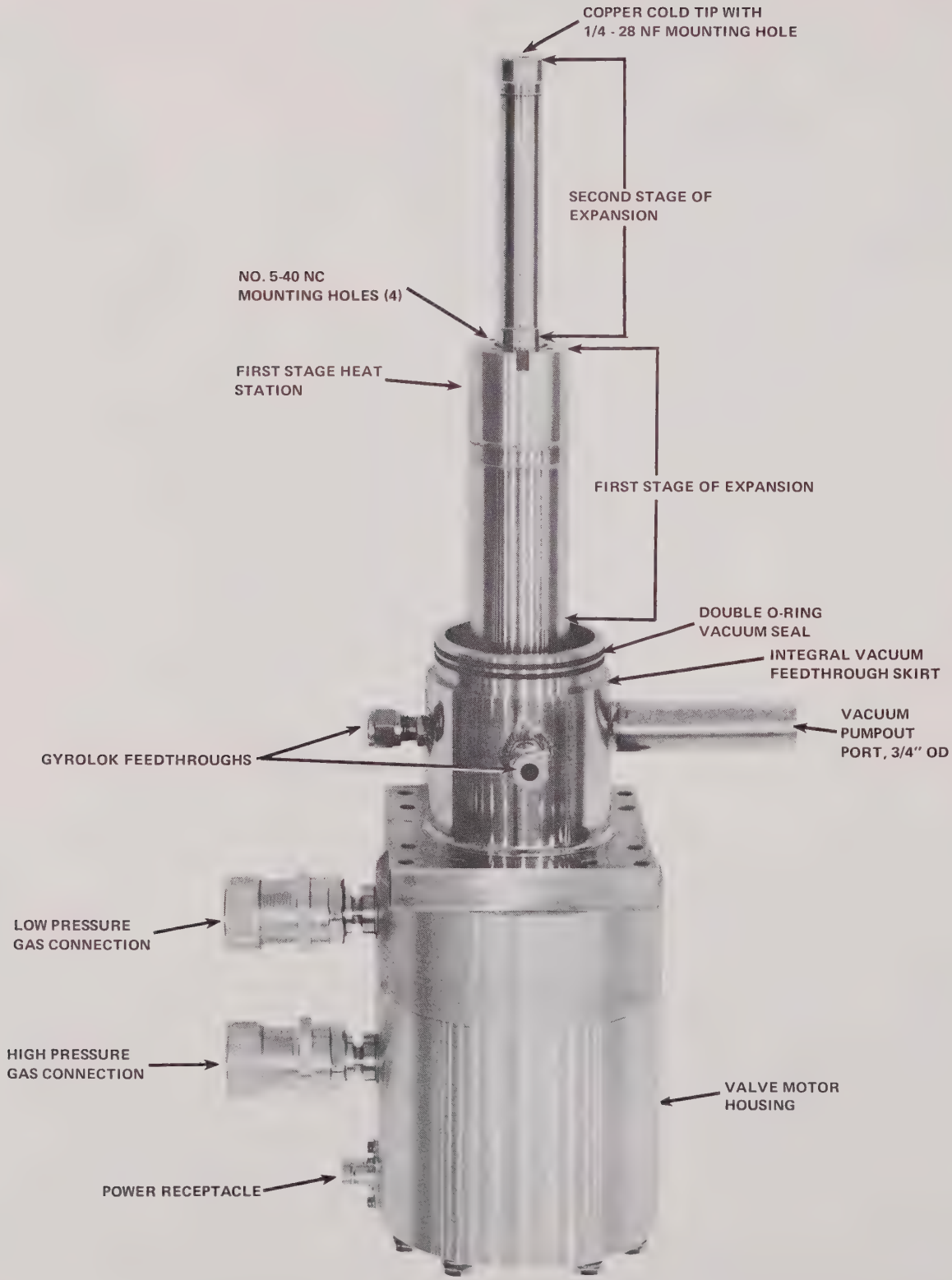


Figure 3-4 DE-202 Expander Module With Instrumentation Feedthrough Skirt

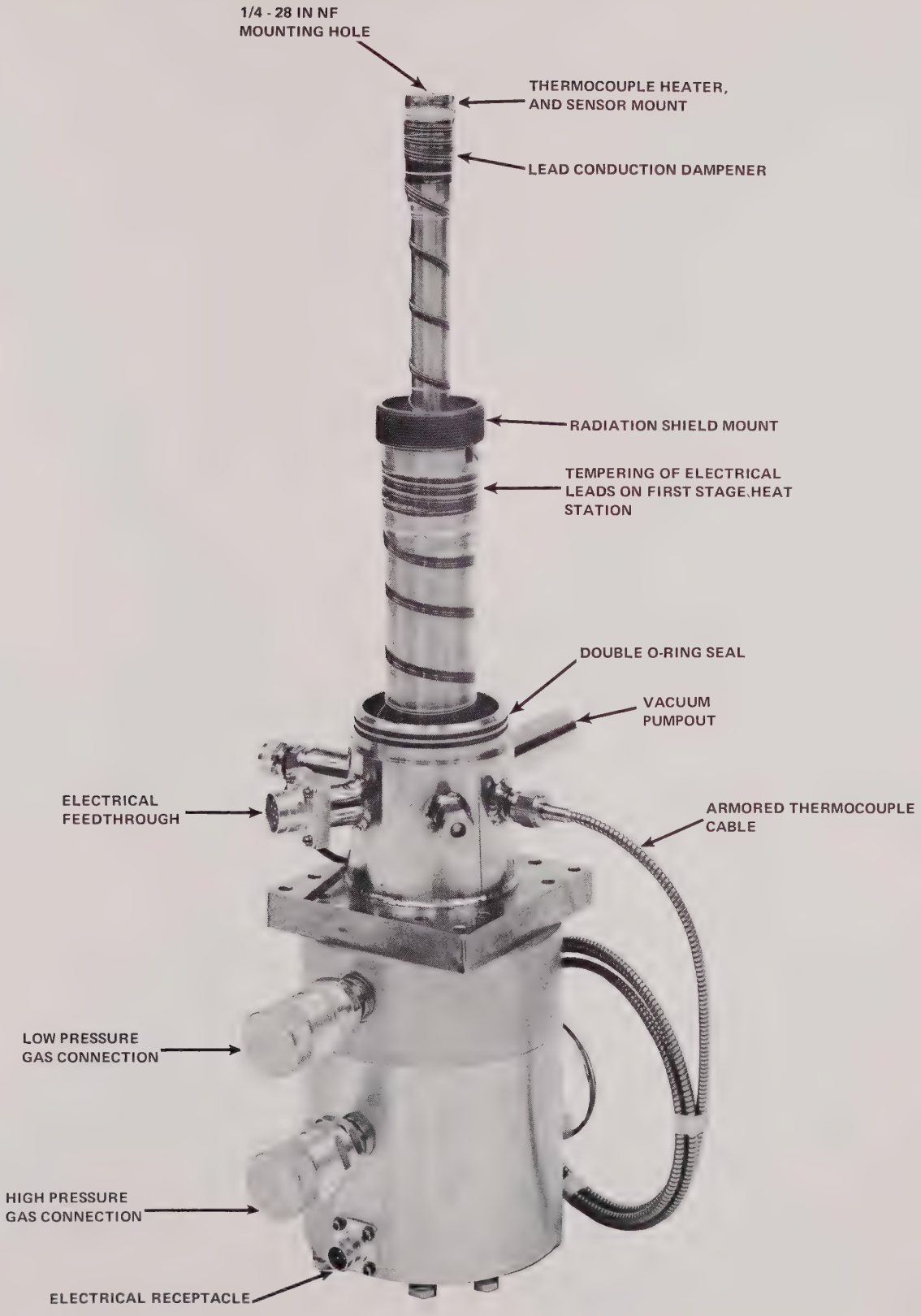


Figure 3-5 DE-202 Expander Module With Instrumentation

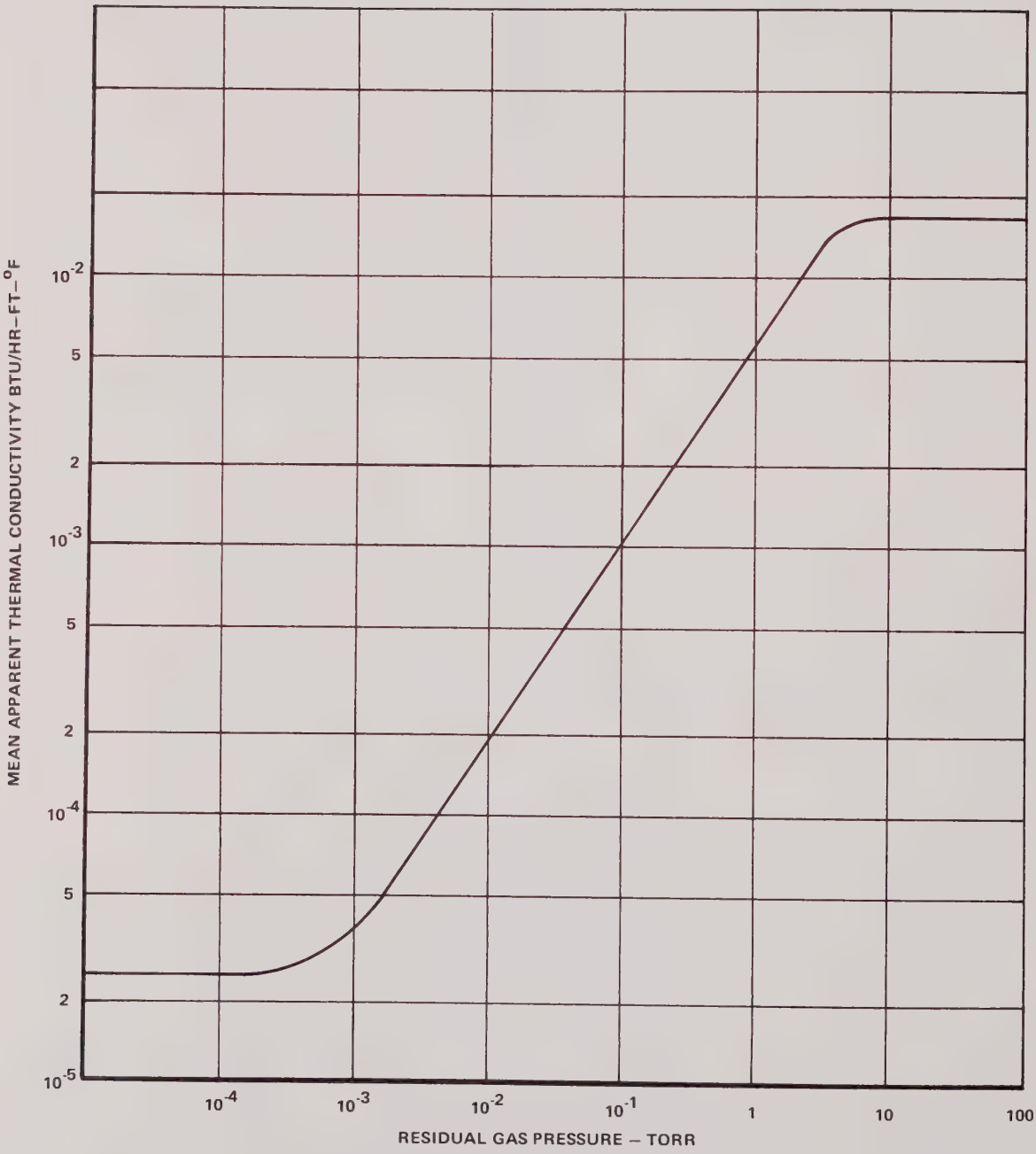


Figure 3-6 Thermal Conductivity As A Function of Pressure

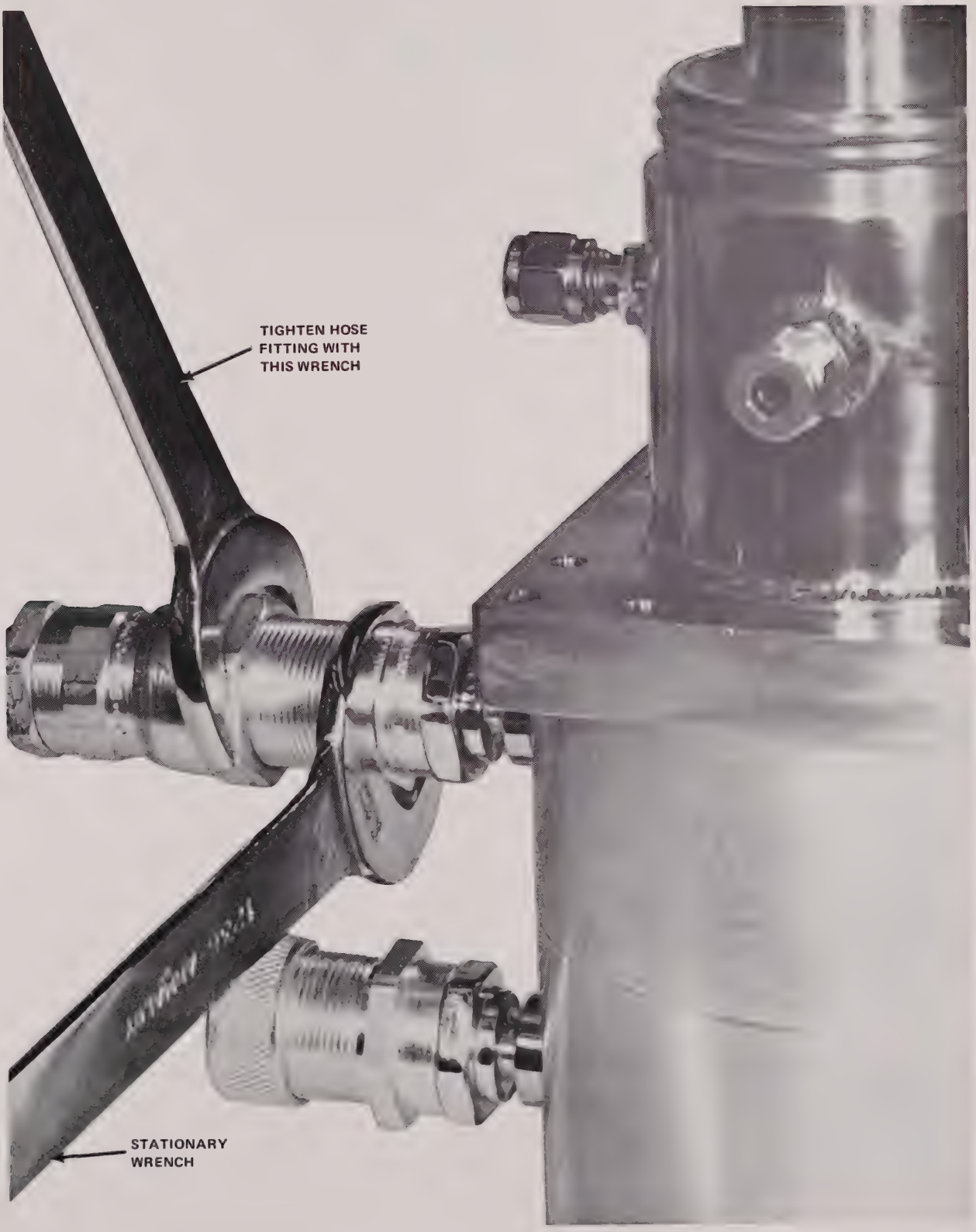


Figure 3-7 Proper Connection of Flexible Gas Lines

SECTION 4
OPERATION AND TROUBLESHOOTING

This section covers the procedures to be followed during startup, cooldown, and steady operation. It also covers techniques which can be used for troubleshooting problems which may arise during operation.

4.1 STARTUP PROCEDURES.

After installation of the system, the following checklist can be used as a guide prior to system startup.

a. Verify that a good insulating vacuum exists in the space about the expander. A vacuum of 5×10^{-3} mm Hg or better is required prior to the start of cooldown. If vacuum is inadequate or if there is a leak it will show up during cooldown by the vacuum shroud feeling a few degrees colder than before cooldown and an inability of the unit to reach minimum temperature.

b. Check the interconnecting lines between the compressor and expander.

(1) High pressure line must be connected to proper fittings at both the expander and compressor. At the compressor, the high-pressure fitting is labeled "Gas Supply." The fittings at the expander are color-coded. Similarly, the low pressure line must be properly connected. The fitting for low pressure is labeled "Gas Return" at the compressor.

(2) Check that the self-sealing couplings have been completely coupled to give a sealed connection for gas flow. Avoid excessive bending or twisting in these lines. The minimum bend radius is 12".

CAUTION

Repeated twisting or bending could cause a failure in the line and loss of gas pressure.

(3) Check that the valve motor power cord which leads from the compressor module to the expander module is connected.

c. Check to make sure the system is fully charged to a pressure of 215 +0/- 5 psig. This can be verified by reading the two gauges on the compressor.

d. Check to see that the temperature readout and/or controller that might be attached is operating. If the system was supplied with a temperature controller or readout, operating instructions are covered in Appendix E.

e. Check to be sure that electrical power is supplied to the compressor. Prior to initial start check for proper voltage per paragraph 3.1 in Section 3.

f. Record initial conditions (e.g., vapor bulb pressure, temperature and gas pressure).

This completes a normal preparation for startup. If special accessories such as a temperature controller are in use, procedures for use of these items are contained in Appendix E.

4.2 COOLDOWN AND STEADY OPERATION

The rate of cooldown is dependent primarily upon the mass which is externally attached to the cold end of the expander, and to

a less extent, the number of conducting heat paths leading to the second stage. Figure 4-1 shows two typical cooldown curves and performance data for the CS-202 system. The items attached to the cold end are listed next to the curves. The two curves in Figure 4-1 demonstrate the approximate limits for minimum and maximum cooldown time. The rate of cooldown is an indication of the load carrying capacity of the refrigerator. It is recommended that the cooldown time be recorded. If the cooldown time is longer than normal it can indicate a loss of vacuum or refrigeration.

The system is started by turning the "OFF-ON" switch to "ON" at the compressor module. This will start the compressor and the valve motor. With an initial charge pressure of 215 $+0/^{-5}$ psig, the pressure should establish itself at 320-330 psig on the high pressure gauge and 110-120 psig on the low pressure gauge. During cooldown, the suction and discharge pressure will decrease by approximately 5 psi. A light tapping noise may be heard during the initial 15-30 minutes of operation. If temperature is being monitored by using a Chromel vs. Gold thermocouple and potentiometer, a calibration table and curve for the particular thermocouple is supplied with each system. Also a general calibration table may be found in Appendix D. This table needs to be shifted for an ice junction reference. The notes with this table provide instructions for doing this. The NBS table gives average millivolts vs. temperature readings. It has been our experience that different Bars of thermocouple wire will shift the chart slightly at the lower temperatures.

The minimum temperature and operating temperature which the refrigerator reaches is a function of how much heat leak exists into the cold tip area. This may vary for each user's system; however, the basic refrigeration capacities are shown in Figure 4-1. The CS-202 curves are based on a typical application having two heater and two thermocouple leads into the second stage. Using Figure 4-1, for example, an imposed heat load of 2.0 watts would result in a tip temperature of approximately 20°K. This curve can be used as a guide then for establishing both the intrinsic load on the device and also what imposed load is required to achieve a given temperature.

On normal shutdown the "OFF-ON" switch on the compressor module shuts down the entire system. After shutdown, the high pressure should decay to 250 psig in less than 90 seconds. If decay time is longer, this indicates a possible blockage in the oil return capillary.

When restarting the system, if the system pressures are not equalized, the startup load on the compressor may be great enough to prevent starting. Wait until pressures equalize before attempting startup.

4.3 FAILURES, UNPLANNED SHUTDOWNS, AND UPSETS.

This section is basically a troubleshooting guide for those times when the system malfunctions during operation, does not start, or an unplanned shutdown occurs. The interest here is to generalize on the description of potential problems and thus encompass many corrective action procedures. This will allow prompt correction by the customer in the field.

The following pages contain several tables which list problems, possible causes, and corrective action. The tables are segregated into air-cooled compressor, water-cooled compressor, and expander. The possible causes and corrective action listed in the table are shown with most likely problems first; thus, the user should investigate the possible causes in the order in which they are listed.

TABLE 4-1
AIR-COOLED COMPRESSOR TROUBLESHOOTING GUIDE

oblem	Possible Causes	Corrective Action
Compressor does not start when switched on, or compressor runs briefly (2-3 seconds) and shuts down.	(a) No power.	(a) Check to see electrical power is being supplied to compressor.
	(b) Low pressure/high pressure cutout not reset.	(b) Push reset button on right-hand side of compressor.
	(c) Insufficient gas charge resulting in low pressure cutout.	(c) Check the system pressure. If less than 195 psig but greater than 10 psig recharge system to 215∓5 psig per section 3.4. If pressure is less than 10 psig, charge and cleanup is required. Refer to section 3.4. Leak check system and repair leak. Push reset button on right-hand side of compressor.
	(d) Excessive pressure causing high pressure cutout.	(d) Check system pressure. If greater than 220 psig vent sufficient gas to obtain equalization pressure of 245∓5 psig. Push reset button on right hand side of compressor.
	(e) Overload protector on compressor is activated.	(e) Check to be sure pressures are equalized, wait several minutes until automatic reset occurs and restart. If shutdown reoccurs, check for problems below.

WARNING

The following procedures should be done by a qualified electrician.

TABLE 4-1 (cont.)

Problem	Possible Causes	Corrective Action
	(f) Malfunction in electrical equipment.	(f) Open fuses - check and replace. Check for electrical continuity on the following items (Reference Figure 2-17 for electrical schematic and Figure 2-16 for equipment locations): Check start and run capacitors as follows: Use a Simpson Ohm Meter or equal, set on Rx1000. Disconnect all leads to capacitor(s). Initial reading should be approximately ½ scale reading then a low resistance. If no deflection is observed reverse leads. If still no deflection is observed replace component. Check compressor Overload Protector as follows: This check must be done with the compressor cold. Check continuity; if open, replace. Check for electrical grounds in the area of the following components: Capacitors Compressor Overload Protector Compressor Relay Pressure Switch Transformer Replace components if required.
	(g) Compressor Drive Motor is stalled.	(g) Measure the current drawn by the compressor during the attempted startup. This is most easily done with a clip-on style ammeter at the compressor connections. Locked rotor condition is 25 amperes. Normal operating current is 6.5 - 7.8 amperes. Startup current may peak at 20-30 amps. for a second or two. If locked rotor is confirmed contact factory.

TABLE 4-1 (cont.)

Problem	Possible Causes	Corrective Action
2. Compressor shutdown and/or intermittent operation.	(a) High temperature ambient (in excess of 100°F) causing overload protector to activate.	(a) Provide cooler ambient. Check to see that cooling coil is clean and air flow is unobstructed.
	(b) Inoperable cooling fan.	(b) Visual inspection and correction.
	(c) Low voltage causing high current, overheating, and overload shutdown.	(c) Check line voltage. Check compressor voltage. If not compatible rewire transformer per Table 3-1.
	(d) Loss of cooling oil flow resulting in compressor overheating and shutdown on overload.	(d) Visual inspection of the oil pump to determine that it is turning. Case is open, allowing for inspection of the motor winding and rotor. If pump is stalled, pump motor contains internal overload protection independent from the rest of the system.
	(e) Blocked oil return capillary causing oil starvation at the compressor.	(e) Shut down, vent the system to 14.7 psia pressure. Remove the capillary fitting at the oil separator, and measure the gas flow between the removed fitting and the "Vent" fitting on the compressor. At 100 psi pressure difference, the flow should be 0.28 ∓ .02 scfm. If blockage is indicated, replacement capillary assembly can be supplied as a spare part or defective capillary can be cleaned.
	(f) Oil filter blocked.	(f) Shut down, vent the system to 14.7 psia. Remove filter and clean.

TABLE 4-1 (cont.)

Problem	Possible Causes	Corrective Action
3. Gradual loss of helium gas charge as shown by pressure reduction (5-50 psi per day).	Leaking fitting or installed component.	Bubble leak check using a soap solution or commercial product. Check the following areas: (a) All compression fittings (b) Bellows assembly at the pressure switch (c) Atmospheric relief valve (d) Oil pump connections and housing (e) Self-sealing coupling fittings (f) All soldered connections

TABLE 4-2
WATER-COOLED COMPRESSOR TROUBLESHOOTING GUIDE

Problem	Possible Causes	Corrective Action
1. Compressor does not start when switched on, or compressor runs briefly (2-3 seconds) and shuts down.	(a) No power.	(a) Check to see electrical power is being supplied to compressor.
	(b) Low pressure/high pressure cutout not reset.	(b) Push reset button on right-hand side of compressor.
	(c) Insufficient gas charge resulting in low pressure cutout.	(c) Check the system pressure. If less than 195 psig but greater than 10 psig recharge system to 215∓5 psig per section 3.4. If pressure is less than 10 psig, charge and cleanup is required. Refer to section 3.4. Leak check system and repair leak. Push reset button on right-hand side of compressor.
	(d) Excessive pressure causing high pressure cutout.	(d) Check system pressure. If greater than 220 psig vent sufficient gas to obtain equalization pressure of 245∓5 psig. Push reset button on right-hand side of compressor.
	(e) Overload protector on compressor is activated.	(e) Check to be sure pressures are equalized, wait several minutes until automatic reset occurs and restart. If shutdown reoccurs, check for problems below.

WARNING

The following procedures should be done by a qualified electrician.

TABLE 4-2 (cont.)

Problem	Possible Causes	Corrective Action
	(f) Malfunction in electrical equipment.	(f) Open fuses - check and replace. Check for electrical continuity on the following items (Reference Figure 2-17 for electrical schematic and Figure 2-16 for equipment locations): Check start and run capacitors as follows: Use a Simpson Ohm Meter or equal, set on Rx1000. Disconnect all leads to capacitor(s). Initial reading should be approximately ½ scale reading then a low resistance. If no deflection is observed reverse leads. If still no deflection is observed replace component. Check compressor Overload Protector as follows: This check must be done with the compressor cold. Check continuity; if open, replace. Check for electrical grounds in the area of the following components. Capacitors Compressor Overload Protector Compressor Relay Pressure Switch Transformer Replace components if required.
	(g) Compressor Drive Motor is stalled.	(g) Measure the current drawn by the compressor during the attempted startup. This is most easily done with a clip-on style ammeter at the compressor connections. Locked rotor condition is 25 amperes. Normal operating current is 6.5 - 7.8 amperes. Startup current may peak at 20-30 amps. for a second or two. If locked rotor is confirmed contact factory.

TABLE 4-2 (cont.)

Problem	Possible Causes	Corrective Action
2. Compressor shut-down and/or in-termittent operation.	(a) High temperature ambient (in excess of 80°F).	(a) A water chiller is recommended for regions with high water temperature.
	(b) Loss of cooling water flow.	(b) Verify that there is no interruption of the sources of water supply such as a closed valve. Verify that inlet solenoid valve opens when system switch is in the "ON" position. These two components are interlocked such that the valve is closed when the switch is in the "OFF" position. (Normally closed, energize to open.)
	(c) Low voltage causing high current, over-heating, and over-load shutdown.	(c) Check line voltage. Check compressor voltage. If not compatible rewire transformer per Table 3-1.
	(d) Blocked oil return capillary causing oil starvation at the compressor.	(d) Shut down, vent the system to 14.7 psia pressure. Remove the capillary fitting at the oil separator, and measure the gas flow between the removed fitting and the "Vent" fitting on the compressor. At 100 psi pressure difference, the flow should be 0.28 $\mp$ .02 scfm. If blockage is indicated, replacement capillary assembly can be supplied as a spare part or defective capillary can be cleaned.

TABLE 4-2 (cont.)

Problem	Possible Causes	Corrective Action
3. Gradual loss of charge as shown by pressure reduction (5-50 psi per day).	Leaking fitting or installed component.	Bubble leak check using a soap solution or commercial product. Check the following areas: (a) All compression fittings (b) Bellows assembly at the pressure switch (c) Atmospheric relief valve (d) Oil pump connections and housing (e) Self-sealing couplings (f) All soldered connections

TABLE 4-3
EXPANDER MODULE TROUBLESHOOTING GUIDE

Problem	Possible Causes	Corrective Action
1. Expander fails to start when system switch is turned on (compressor running).	(a) Valve motor power cord is not connected.	(a) Connect power cord.
	(b) Valve motor malfunction.	(b) Check continuity of motor by removing the power cord and measuring resistance between pins. Values should be: 1-2 — 2000 ohms 2-3 — 1000 ohms 1-3 — 1000 ohms Replace valve motor.
2. Expander valve motor turns, system does not cool down.	(a) Incorrect instrumentation hookup or installation.	(a) Reference installation Figures in Appendix D for correct thermocouple installation. Check Appendix E for accessory information.
	(b) Lack of insulating vacuum.	(b) Check vacuum pressure inside of shroud using vacuum gauge if available. Reference Figure 3-8. Locate and repair leak.
	(c) Gas lines are not connected, poorly connected or connected to the wrong fittings.	(c) Check these connections.
	(d) Compressor is not developing full flow and full head pressure.	(d) Check pressure gauges. Disconnect the expander power cord and gas lines and run the compressor independently. Follow checkout in Table 4-1 or 4-2.

TABLE 4-3 (cont.)

Problem	Possible Causes	Corrective Action
	(e) Piston assembly is "frozen" in the cylinder, possibly due to contamination.	(e) Return to APCI for servicing. This is an unlikely occurrence. All potential problems should be thoroughly investigated before returning the unit to the manufacturer. The contamination could result from air and other condensables in the gas or oil carryover from the compressor. If the latter is suspected, disassembly and visual inspection will be adequate to verify this problem. (See (c) below.)
3. Noisy operation after a sustained period of operation (i.e., greater than ½ hour).	(a) Incorrect pressure levels at the compressor.	(a) Reference 2(d) and 2(e) above.
	(b) Contamination in the gas inventory.	(b) Allow the entire system to warm up to ambient temperature. Disconnect the expander and compressor by removing the gas lines at the expander. Leave the hoses connected to the compressor. Follow the cleanup procedures in Section 3.3.1 and 3.3.2.
	(c) Oil carryover from the compressor has occurred, thus contaminating the expander.	(c) Disconnect the self-sealing coupling on the outlet side of the oil adsorber. Inspect for significant quantities of oil. If oil is present, disassemble the expander and follow cleanup procedures described in Section 5.2.3. Also inspect all of the fittings on the interconnecting flex lines for evidence of oil.
4. Intermittent operation.	(a) Compressor is cycling on and off.	(a) Reference Tables 4-1 and 4-2.

TABLE 4-3 (cont.)

Problem	Possible Causes	Corrective Action
	(b) Contamination in the gas inventory causing the expander piston to freeze up, warm, thaw and recycle.	(b) Reference 3 (b) above.
. Sudden loss of refrigeration capacity.	(a) Loss of insulating vacuum.	(a) Check all O-ring joints for possible vacuum leaks (e.g., shroud windows, shroud double O-ring seal, and all feedthroughs).
	(b) Compressor malfunction.	(b) Reference Table 4-1 or 4-2.
	(c) Valve motor discontinuity or failure.	(c) Reference 1 (b) above.
	(d) Sudden application of heater power.	(d) Check condition and setting of temperature controller.
. Slow loss of refrigeration capacity.	(a) Small vacuum leak.	(a) Check all O-ring seals.
	(b) Worn seals.	(b) Refer to maintenance procedure in Section 5.1. Leaking seals will show a "streaming" deposit pattern of black particles on the displacer in the vicinity of the rings.
'. Loss of pressure in the expander.	(a) Leakage at fittings or sealing surfaces.	(b) Check self-sealing fittings. Check electrical valve motor receptacle which has an O-ring seal. Check O-ring seal between motor base and flange and motor base and valve motor housing. Check flex lines and fittings independent from the remainder of the system.

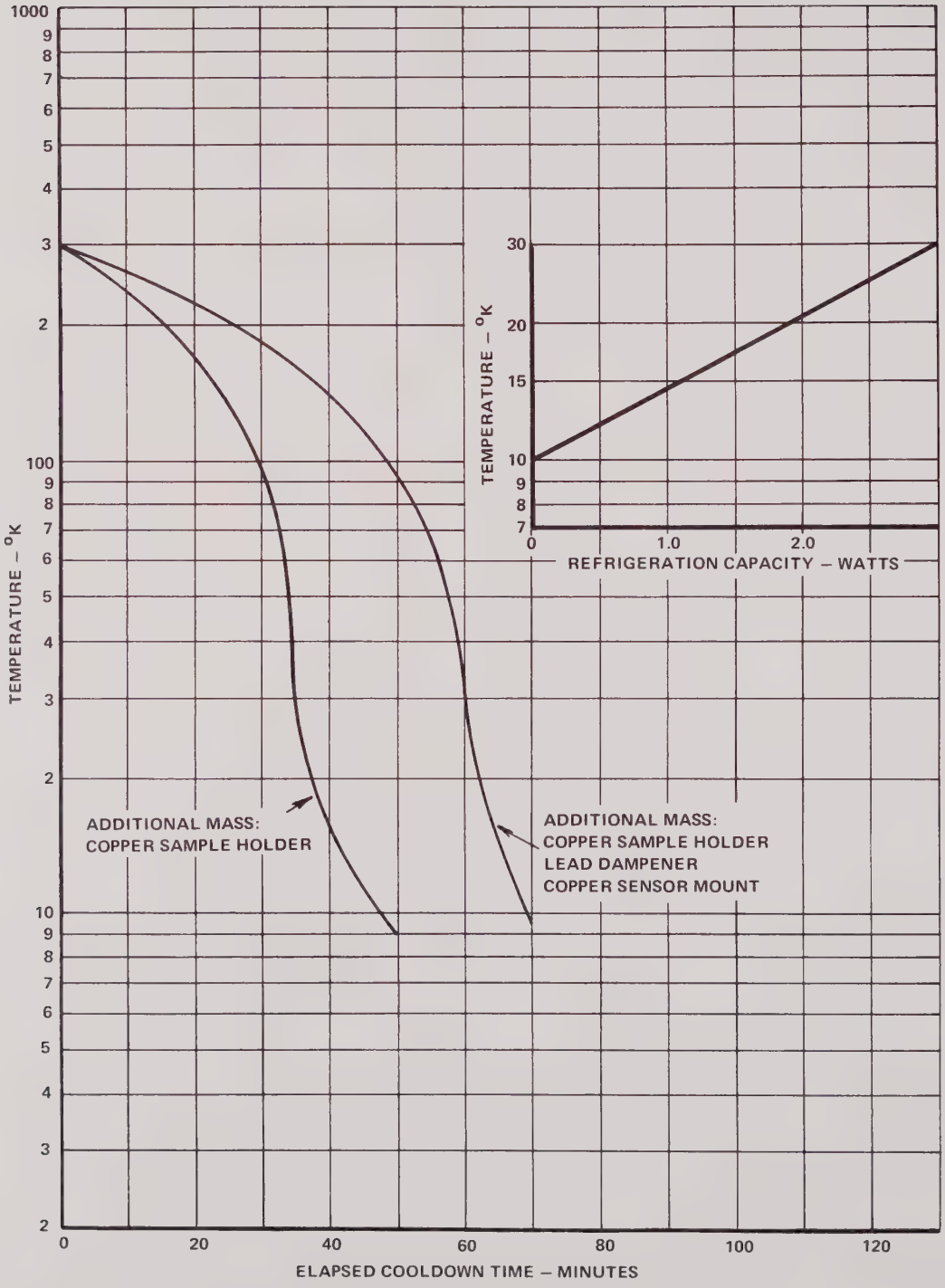


Figure 4-1 Typical Cooldown and Performance Curves For CS-202 System

SECTION 5
SYSTEM MAINTENANCE

This section covers all of the maintenance procedures for the Displex CS-202 system. The section is divided into two major subsections: planned maintenance procedures and unplanned maintenance procedures. The planned items are those required at fixed operating time intervals. The second category covers those items which may arise on an irregular basis due to malfunction or adverse ambient conditions.

It is assumed that all maintenance will be performed by a skilled mechanic or technician. The following warning notes must be adhered to prior to performing any maintenance.

WARNING

Do Not Disassemble or remove any component before venting all of the gas from the internal working volume(s).

WARNING

Disconnect electrical supply at customer disconnect before removing compressor cover.

5.1 PLANNED MAINTENANCE.

The expander module may be operated indefinitely with no maintenance. If a degradation in performance is observed, it may be corrected by replacing the seals and/or valve disc. Prior to seal replacement it is recommended to first check other possible causes as outlined in Table 4-3 — Expander Module Troubleshooting Guide. A guideline for the replacement can be every 9,000 hours of operation for expander seals and backup O-rings, and 18,000 hours for valve disc. It must be emphasized, however, that this replacement is not required and will not cause damage to the machine if not performed. A complete explanation of expander module seal and valve disc replacement is covered in sections 5.1.1 and 5.1.2.

The compressor module requires periodic maintenance every 9,000 hours of system operation in that the charcoal adsorber must be replaced. Replacement of the adsorber is explained in section 5.1.3.

5.1.1 Replacement of Expander Seals. The following procedure is to be followed when replacing the expander seals.

WARNING

Observe warnings that appear before section 5.1.

a. With the expander at room temperature, remove the interconnecting lines at the expander module. (Reference Figure 3-7 for proper wrench positions.) This isolates the expander module from the rest of the system and thus avoids introduction of contaminants into the compressor module and interconnecting lines. It is generally convenient to leave the vacuum shroud on the cold end as a protective measure. Place the expander in an upright position with the cold tip pointed down. A ring stand is convenient for securing the unit. A bench vise can also be used. Clamp on the cylinder flange if using a vise.

b. Attach adapter fittings to the high- and low-pressure fittings at the expander and vent the entire gas charge. Run the compressor with the valve motor cable connected while venting so as to purge all gas. Remove adapters.

c. Remove the eight ⅜" head bolts. These extend through the valve motor housing, motor base, and into the warm flange. (Reference Figure 5-1 for the DE-202 expander.)

d. Lift the entire valve motor assembly (valve motor housing, motor base, valve disc, and valve stem) from the cylinder and displacer. This entire sub-assembly should be able to be removed with gentle pressure. There are no internal connections. The only resistance will be the resistance of the lower half of the valve stem on the seals. Set the valve motor assembly aside. At this point the dispacer assembly should still remain in the cylinder. Do not pull the valve stem out of the motor base if only seal maintenance is to be performed.

WARNING

Observe warnings that appear before section 5.1.

e. Remove the displacer assembly. Use SK-8201A Piston Puller inserted in the tapped hole on the top of the coupling plug. (Reference kit items in Appendix C.) This allows one to pull the expander out of the cylinder. (Reference Figure 5-2 for location of the coupling plug.)

NOTE

Do not allow piston assembly to remain exposed to atmosphere for extended period of time. The material from which it is fabricated will absorb water vapor, causing the assembly to swell.

NOTE

It is recommended to keep the piston assembly in a sealed plastic bag when work is not being done. Exposure should not exceed two hours in a normal air-conditioned environment. If the diameter in the center of the first stage piston exceeds 1.498", then the piston assembly should be vacuum baked. Bake entire displacer assembly in a vacuum oven at 150°F for 12 to 16 hours. Allow oven to cool prior to breaking vacuum with dry nitrogen.

f. With the displacer free to be worked on separately, remove all of the seals and backup O-rings. Do not remove the garter spring behind the second stage rings on the DE-202. In so doing, note the condition of the rings and the manner in which they are installed.

g. Install new O-rings into the empty grooves. These O-rings are included in the Spare Parts kit but can also be ordered separately. They provide the required force to seal the crescent ring seals against the first-stage cylinder walls and valve stem. The garter springs provide the proper force to seal the second-stage crescent rings seals.

h. Install only new rings supplied by Air Products and Chemicals. These rings have been prepared to give the best performance in your system. For correct installation, these rings must be properly dressed and fitted.

(1) Proper dressing of a crescent ring is done with the use of the appropriate crescent ring dressing tool. There are three such tools for the three basic sizes of rings: first stage and outside slack cap (SK-8196A dressing tool), inside slack cap (SK-8197A dressing tool), and second stage (SK-8198A dressing tool). These tools are included in the Special Tools Kit but can also be ordered separately. The tools essentially consist of a flat metal disc with a machined groove. New crescent ring seals should be sized and finished by placing

them in the groove, turning the disc upside down, and rubbing with a back and forth motion on a flat surface covered with 600-grit silicon carbide paper. Both sides of the crescent ring should be finished in this manner. This insures a smooth polished finish on both sides of the crescent ring. A small hole is drilled through the crescent ring dressing tool to assist in removing the ring.

NOTE

Be careful to minimize material removal to prevent the seals from becoming undersize [see h. (2)(a)].

WARNING

Observe warnings that appear before section 5.1.

(2) Proper fitting of the crescent rings is checked with a ring seating tool for the second-stage rings (SK-8199A ring seating tool) and another ring seating tool for the inside slack cap rings (SK-8200A ring seating tool). These two seating tools are included in the Special Tools Kit but can also be ordered separately. The cylinder assembly can be used to properly fit the first stage and outside slack cap rings.

(a) Second-stage crescent rings - the two rings should be properly dressed as described in h(1) and slipped over the tip of the displacer second stage. They should be slipped into the groove provided, with the crescent cuts oriented at 180° from each other. Refer to Figure 5-6 for proper orientation of the crescent rings. These rings will have a snug fit and should not be rotatable once installed. Since the seals are designed to provide a seal axially rather than radially as in the other expander seals, the fit of these seals to the groove is critical. It is essential to ensure that:

. . . both sides of the seals have been dressed to give a flat surface and a 32 micron finish or better.

. . . the seals, although a snug (approximately 0.0005" less than the groove) fit, do not bind in the groove.

The second-stage ring seating tool SK-8199A should then be slipped over the displacer second stage to seat the crescent rings into their proper position. If the seals are too tight, they will be forced into the groove and will not *slightly* expand when the piston is removed from the seating tool.

If the seals are too loose, the seals will pop from the groove when the piston is removed from the seating tool. If this condition occurs and is not remedied, it is likely that the seals will be damaged when the piston assembly is attempted to be entered into the cylinder assembly.

(b) Inside slack cap crescent rings - these rings should be properly dressed and inserted into the groove provided on the inside of the slack cap. The crescent cuts should be oriented 180° apart, and the rings should be properly fitted into position with the slack cap ring seating tool SK-8200A. Refer to Figure 5-6 for proper orientation of the crescent rings. The seal-to-groove fit on these seals is less critical than the second-stage seals and may therefore be a looser fit since the seal is radial and is provided by the backup O-ring.

(c) First-stage and outside slack cap crescent rings - a total of four (4) rings should be properly dressed as described above and slipped into position on the slack cap and first stage such that the crescent cuts in the rings occupying the same groove are 180° apart. Refer to Figure 5-6 for proper orientation of the crescent rings. When properly fitted, these seals should be able to be rotated in their grooves by using the tips of the thumb and index finger and lightly turning. The entire displacer assembly can then be inserted into the cylinder assembly. This should seat the new crescent rings on the displacer first stage

and outside slack cap. As in h(2)(b) these seals provide a radial seal by virtue of the backup O-ring and are therefore not as critical in the seat-to-groove fit as the second-stage seals.

i. Re-assemble the cold head by installing the displacer assembly. Twenty to thirty pounds of force is required to push the displacer assembly down to the bottom of the cylinder. With the displacer in the cylinder, install the valve motor assembly. Gently push this sub-assembly into place so as not to damage the stem rings as the valve stem slides into place.

NOTE

SK-8200A, ring seating tool, should be inserted prior to inserting the valve motor assembly. The more gradual taper on this tool prevents seal damage and seats the rings to allow insertion of the stem.

WARNING

Observe warnings that appear before section 5.1.

j. Bolt the assembly together using the ¼'' head bolts. When tightening, partially tighten the bolts in a criss-cross pattern, always moving to the next bolt across the head. When all bolts are snug, torque to 120 in-lbs.

5.1.2 Valve Disc Replacement. The following procedure is to be followed when replacing the valve disc.

If the valve disc maintenance is to be done in conjunction with the seal maintenance, then steps a through d of Section 5.1.1 apply here. They also apply if valve maintenance is undertaken separately.

Follow steps a through d in Section 5.1.1 as preparation for replacing the valve disc. With these completed, follow the steps listed below.

a. Remove the valve stem from the motor, place two screwdrivers underneath the valve stem assembly and gently pry the assembly upward. Set the valve stem aside, being careful not to scratch the two dark, hard-coated surfaces.

b. Place the motor housing and base right-side up into your hand and catch the disc. Do not separate the base and motor housing. They are connected by two machine screws.

c. Place the motor base and housing upside down so that the motor shaft can be viewed directly. There are two roll pins installed in the motor shaft with a light spring trapped between the pins.

d. Slide the new valve into place over the end of the shaft. This valve has been specially prepared to have a good sealing surface. Take all precautions not to scratch or mar this polished surface. With the valve installed, flex it against the spring a few times to make sure the spring is not hung up and that adequate clearance between the disc and roll pins is provided.

e. Install the valve stem.

f. Reassemble the unit following steps i and j of Section 5.1.1.

A new valve disc should seat in quickly. No transient performance effects should be noticed. If deficient performance occurs and the valve is suspected of being the cause, inspect the sealing surface for any obvious scratches or imperfections.

5.1.3 Adsorber Replacement. The charcoal adsorber is located in the compressor module and serves the function of removing oil vapors from the helium process stream. Functioning in this manner, it has a finite life. The replacement is total, including the pressure vessel containing the charcoal, the tubing, and the self sealing fittings. This entire assembly is supplied by Air Products and Chemicals, Inc.

WARNING
Observe warnings that appear before section 5.1.

In contrast to the maintenance procedures on the expander module, this is performed with full pressure in the system. The following procedure is to be followed when replacing the adsorber.

a. Remove the compressor module cover. Remove the nut and stud which hold the adsorber to the compressor module base. The nut is located on the underside of the base plate.

b. Loosen and break both self-sealing couplings, shown with wrenches in Figure 5-3. Loosen each coupling a few turns until both couplings are disconnected.

c. Remove adsorber.

d. Install the new adsorber following a reverse of the above steps.

When making and breaking the self-sealing fittings, it is important to loosen the joints at the proper place. Failure to do so will cause a loosening at the O-ring connections and a possible sudden venting of the system pressure. If it is not between 215 +0/-5 psig, then helium will have to be added. Sometimes small amounts of gas are lost when making and breaking the self-sealing couplings.

5.1.4 Self-sealing Fittings. It is recommended although not mandatory that the self-sealing couplings be serviced at the 9,000-hour maintenance intervals. Couplings should only be replaced if leakage cannot be repaired by replacing seal or if galling of the threads prevent installation. This includes the male fitting end (2) on the expander and the O-rings (2). Assuming that less wear has occurred on the compressor fittings since the hoses generally are kept with the compressor, the compressor fittings do not require servicing. If they do, these same procedures would apply.

a. With the flex hoses disconnected at the expander module, vent all of the gas in the expander (reference steps a and b in Section 5.1.1).

b. Separate the two halves of the coupling as shown in Figure 5-4. Do not remove the coupling adapter from the valve motor assembly.

c. Replace the O-ring as shown. Apply vacuum grease to the O-ring to assist in sealing.

d. Install a new outer coupling half. Apply a small amount of vacuum grease to the outer threads to minimize wear. Tighten coupling half to a torque of 20 in.-oz.

5.2 UNPLANNED MAINTENANCE.

There are several maintenance procedures which may be required on an unplanned basis. These problems generally do not occur frequently, but when they do, some specialized procedures and information are necessary. The following sections contain several of the procedures. The sections are listed in their general order of frequency of occurrence and importance.

It is necessary for proper maintenance that failures resulting in unplanned maintenance be thoroughly analyzed and understood to ensure that all necessary remedies be performed. Often times failures in one area can cause future problems if only the failed part is changed without recognizing the need for other service as a result of the initial failure, especially in oil carryover problems. Section 5.2.1 is an example of one failure requiring several areas of service.

WARNING

Observe warnings that appear before section 5.1.

5.2.1 Disassembly and Cleaning of the Expander Module. There may be a requirement at some time in the life of the expander, to thoroughly clean the internal expander assembly. The most likely cause of such a requirement would be gross contamination. Such contamination may occur as a result of oil carryover from the compressor or other failures which would introduce particles into the flex lines and carry to the expander. Such failures are rare and not commonly encountered. If a gross contamination does occur it is absolutely essential to determine the cause of the contamination and repair this before system cleaning. All gas lines in the compressor along with flexible interconnecting lines must be thoroughly cleaned. Normally replacement of the adsorber assembly is also required after oil carryover. It is therefore recommended that the compressor and flexible gas lines be returned to the factory for service. However, if circumstances demand field repair, contact the factory for special instructions. The following procedure is for the cleaning of the expander module only.

When preparing to clean the expander, follow steps a through e in Section 5.1.1.

a. With the unit disassembled, pull the valve stem from the motor base.

b. Inspect all pieces for evidence of contamination.

c. The displacer assembly and cylinder can be washed in Freon TMC solvent. This is very effective and not harmful to the components. Force some of this solvent down through the regenerators to flush any contaminant from these areas. Do not use any solvent on the valve motor area.

d. Remove all of the rings and backup O-rings. Bake the entire displacer assembly in a vacuum oven. Do not exceed 150°F during bakeout or material will be damaged.

e. Clean all O-ring surfaces and O-rings. Apply vacuum grease to O-rings before reinstalling.

f. With a small amount of solvent on a clean cloth, wipe the face of the valve disc clean and the mating surface of the valve stem. The valve stem itself can be immersed in solvent for cleaning the internal passage ways and O-ring grooves.

g. Reassemble the unit, following steps g, h, i and j in Section 5.1.1. (Disregard reference to "New Seals.")

5.2.2 Expander Orifice Flow Measurement. In the process to troubleshooting a problem in the expander module, it may be necessary to flow check the orifice which is located in the valve stem. This orifice serves the purpose of loading the expander and thus removing energy as refrigeration is produced. Its flow characteristics are very important to the performance of the system.

To measure flow, the valve stem must be removed from the expander. Follow the steps listed below:

a. Follow steps a through d in Section 5.1.1.

b. Remove the valve stem. Take care not to damage any of the dark hardcoated surfaces.

WARNING
Observe warnings that appear before section 5.1.

c. Set the stem up for test as shown in Figure 5-5.

d. Press the rubber hose tightly against the face of the stem around the orifice and measure flow at a pressure of 25 cm mercury. The flow should be .12-.14 scfm for the DE-202.

e. If the flow is not in this range, look for contamination in the orifice. If problem is not apparent, contact the manufacturer.

f. Reassemble following steps i and j in Section 5.1.1.

5.2.3 Replacement of Compressor Module Pressure Switch. The replacement of the pressure switch is not a required maintenance item; however, in a few cases failures have occurred in the field due to the natural pulsating pressure in the compressor. The procedure below is a brief outline to be followed if replacement of this item becomes necessary.

NOTE
Do not leave compressor internals exposed to ambient air because the oil absorbs moisture very readily.

a. Disconnect the compressor from the interconnecting flex lines. Leave these lines connected to the expander. This will avoid having to clean up the expander and flex lines after the maintenance is complete.

b. Slowly vent all of the gas in the compressor, using the vent valve on the back of the compressor. Gauges should read 0 after the system is vented.

c. Using a tubing cutter, cut both of the ⅛" tubes leading to the pressure switch at a convenient location between the switch and the point where they are brazed into the ¼" tubes.

d. Remove the bolts which hold the bracket in place and replace the switch.

e. Connect to the old ⅛" lines, using the compression fittings supplied with the replacement switch.

f. Pressurize the system with helium to 215 psig and soap check the compression fitting joints.

g. Follow charge and cleanup procedures in Section 3.3.1.

h. Reassemble the flex lines.

5.2.4 Replacement of Oil Pump on Air-cooled Compressor Module. The replacement of an oil pump on the air-cooled system can be accomplished by following the procedure outlined below:

NOTE
Do not leave compressor internals exposed to ambient air because the oil absorbs moisture very readily.

a. Vent all gas from the system by opening the vent valve on the back of the unit. Gas should read 0 psig when this is completed.

b. Disconnect electrical lines and remove the pump.

c. Loosen the Gyrolok compression fitting below the check valve on the oil pump discharge line. Break the line at tis point. A very small quantity of oil will drain with the check valve, preventing any appreciable quantity from draining.

d. Disconnect the suction line at the compression fitting which is mounted directly on the pump.

e. Remove the two fittings which are installed in the pump, replace the Teflon tape wrapped on the threads, and install these fittings on the new pump.

f. Install the new pump in the compressor module and secure both fittings. Connect the electrical leads.

g. Follow the cleanup procedure in Section 3.3.1. It is not necessary to add oil to the system or prime the pump. When initially running the system after replacing the pump, verify that the motor is turning by visual inspection inside of the motor housing. Check that none of the fittings around the pump are leaking. Verify that oil is being pumped by feeling the discharge tube. If the tube is very hot, oil is being circulated.

WARNING

Observe warnings that appear before section 5.1.

5.2.5 Repair and Replacement of Oil Return Capillary. The following procedure is to be followed when replacing the oil return capillary. Blockage of the capillary can cause compressor shutdown and/or intermittent operation. Blockage is normally indicated when the decay time from operating pressure to 250 psig is greater than 90 seconds as observed on the high pressure gauge located on the front of the compressor module.

NOTE

Do not leave compressor internals exposed to ambient air, because the oil absorbs moisture very readily.

a. Disconnect the compressor from the interconnecting flexible lines. Leave these lines connected to the expander.

b. Slowly vent all of the gas in the compressor, using the vent valve on the back of the compressor. The gauges should read 0 psig after system is vented.

c. Take capillary flow reading to determine if the capillary is blocked.

(1) Disconnect the capillary at the union fitting on the oil separator.

(2) Cap off separator using a ¼ compression cap fitting.

(3) Connect helium supply at the capillary side of the union.

(4) Connect flow meter (or other metering device) at the charge fitting on the rear of the compressor.

(5) Apply helium at 100 psig. The flow through the capillary should be 0.28 ∓ 0.02 scfm.

(6) If the reading is below the required flow, the capillary must be either cleaned or replaced and the oil separator should be purged to remove excessive oil.

d. To clean the capillary filter assembly:

(1) Remove the union fitting from the capillary tube; this fitting contains the filter. This assembly should be cleaned in an ultrasonic cleaner or back flushed using Freon TMC solvent.

(2) Check to insure that the capillary tube itself is not blocked by following the same procedures outlined in step c, with the exception that the union fitting containing the filter is not installed. The flow should be 0.28 ∓ 0.05 scfm. If it is not, replace the capillary assembly.

(3) Reassemble capillary and re-check flow per step c. If flow is still below requirements eplace capillary and/or filter assembly.

e. To replace the capillary:

(1) Remove the capillary by cutting the ⅛" diameter stainless steel tubing at the oil return fitting on the compressor. This must be done with a tube cutter. Care should be taken to cut through the stainless steel tubing only, since the capillary tubing extends the entire length of the stainless steel tubing. This section of capillary tubing must be removed.

(2) The replacement capillary is supplied pre-sized and with the filter assembly installed. A ⅛" compression fitting is also supplied with a Teflon plug installed on one end to provide for easy installation. Insert copper capillary tube through union, first through the end with the Teflon sealant, taking care to insure that none of the Teflon has blocked the capillary. Then push the capillary tubing into the stainless steel tubing until a slight resistance is felt. Finally, tighten both halves of the union.

f. A purge of the oil separator is recommended to remove excessive oil that might have accumulated due to a blocked capillary.

(1) Cap off the capillary at the union fitting.

(2) Connect a helium supply with regulator to deliver low pressure to the charge fitting on the rear of the compressor.

(3) Attach a tubing stub on the separator using a ¼ compression union.

(4) Use a graduated container to connect the oil. (An equal amount of oil must be added to the system at a later time.)

(5) Apply helium at 2 psig. Use a regulator on the helium tank; excessive pressure may damage the separator.

(6) Purge the separator for ½ hour, or until no oil is being purged from the separator.

(7) Clean all fittings and reassemble.

g. Check for oil carryover to the adsorber by inspecting both inlet and outlet self-sealing fittings on the adsorber.

(1) If no oil is present reassemble and follow cleanup procedure in Section 3.3.1.

(2) If oil is present on the inlet fitting only, replace the adsorber per Section 5.1.3.

(3) If oil is present on both fittings, contact the factory for special instructions. This indicates possible oil carryover to the expander.

h. Add an equal amount of oil that was removed during the purge of the oil separator. Use only UCON-LB-300X vacuum baked oil. The oil charge fitting is located on the top of the compressor.

i. Follow the cleanup procedure in Section 3.3.1.

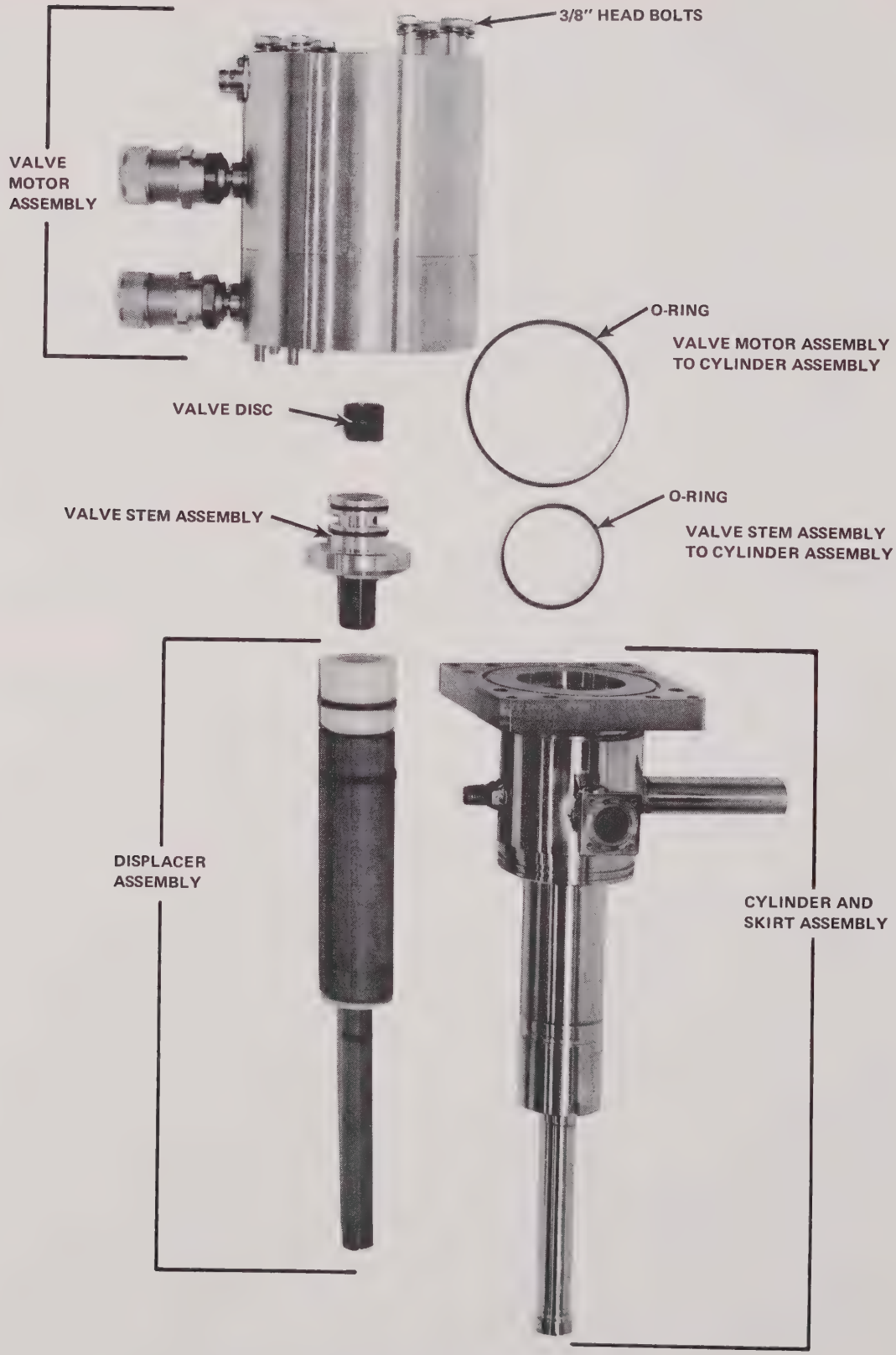


Figure 5-1 Basic DE-202 Expander Components

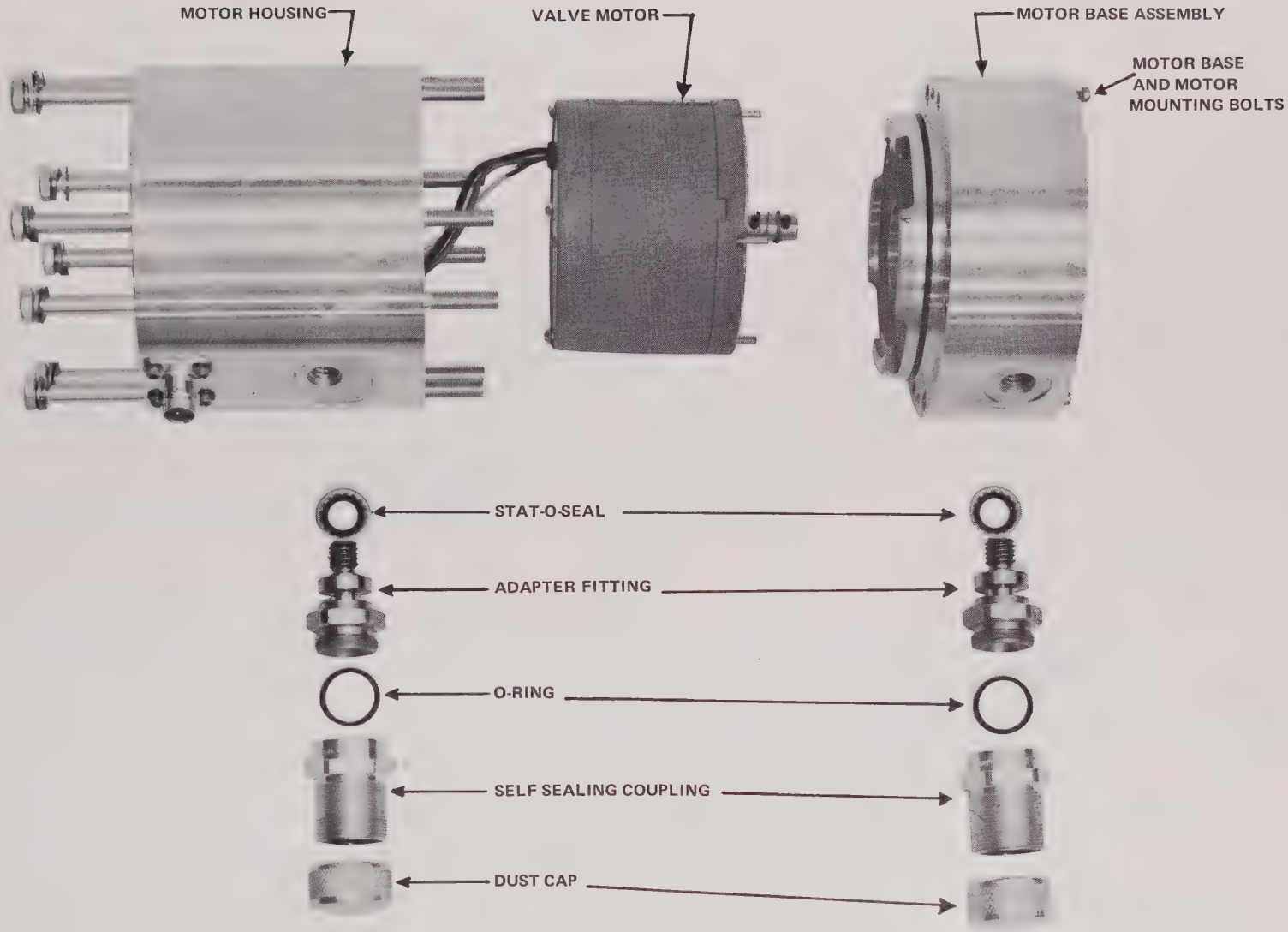


Figure 5-2A Detail of Valve Motor Assembly

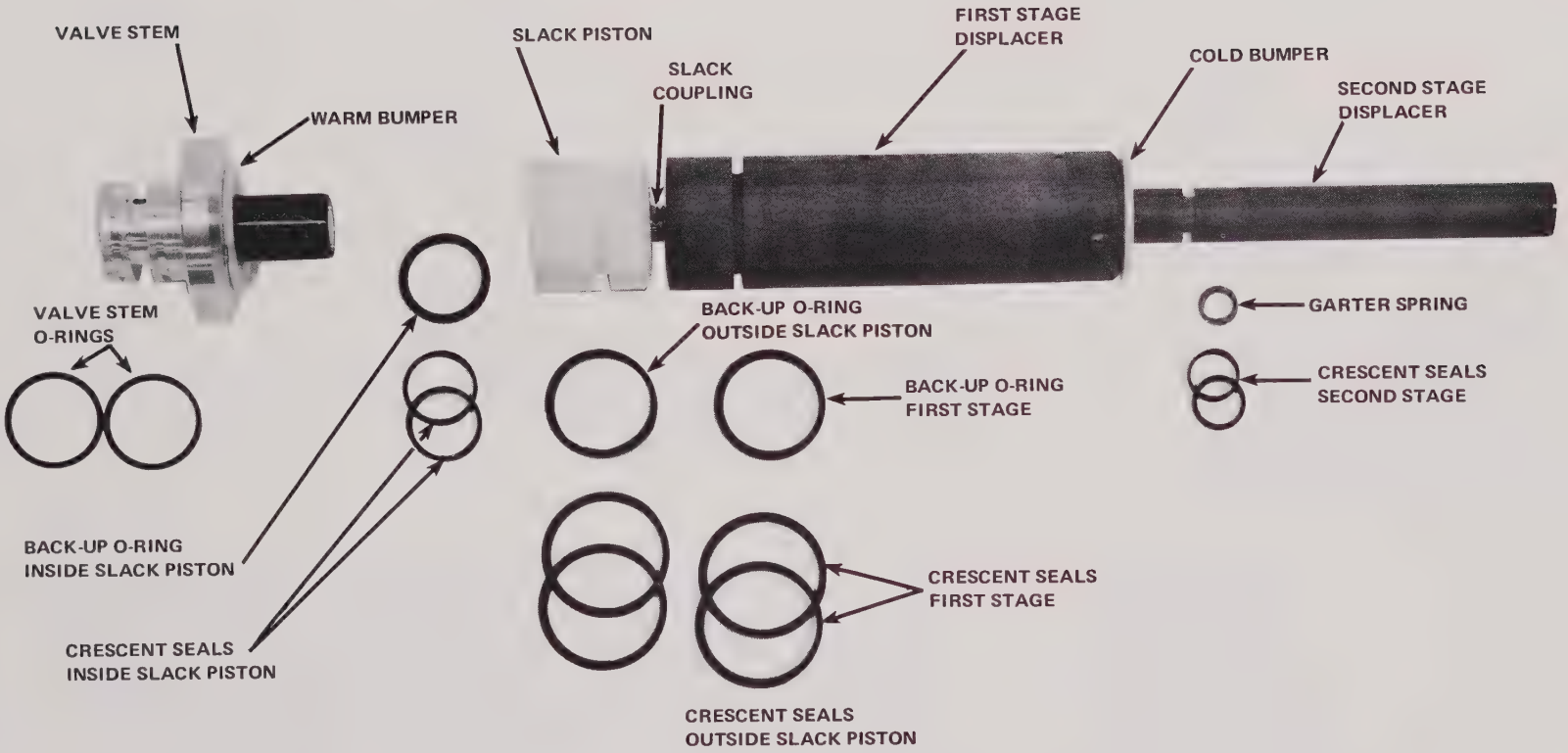


Figure 5-2B Detail of Valve Stem Assembly and Displacer Assembly

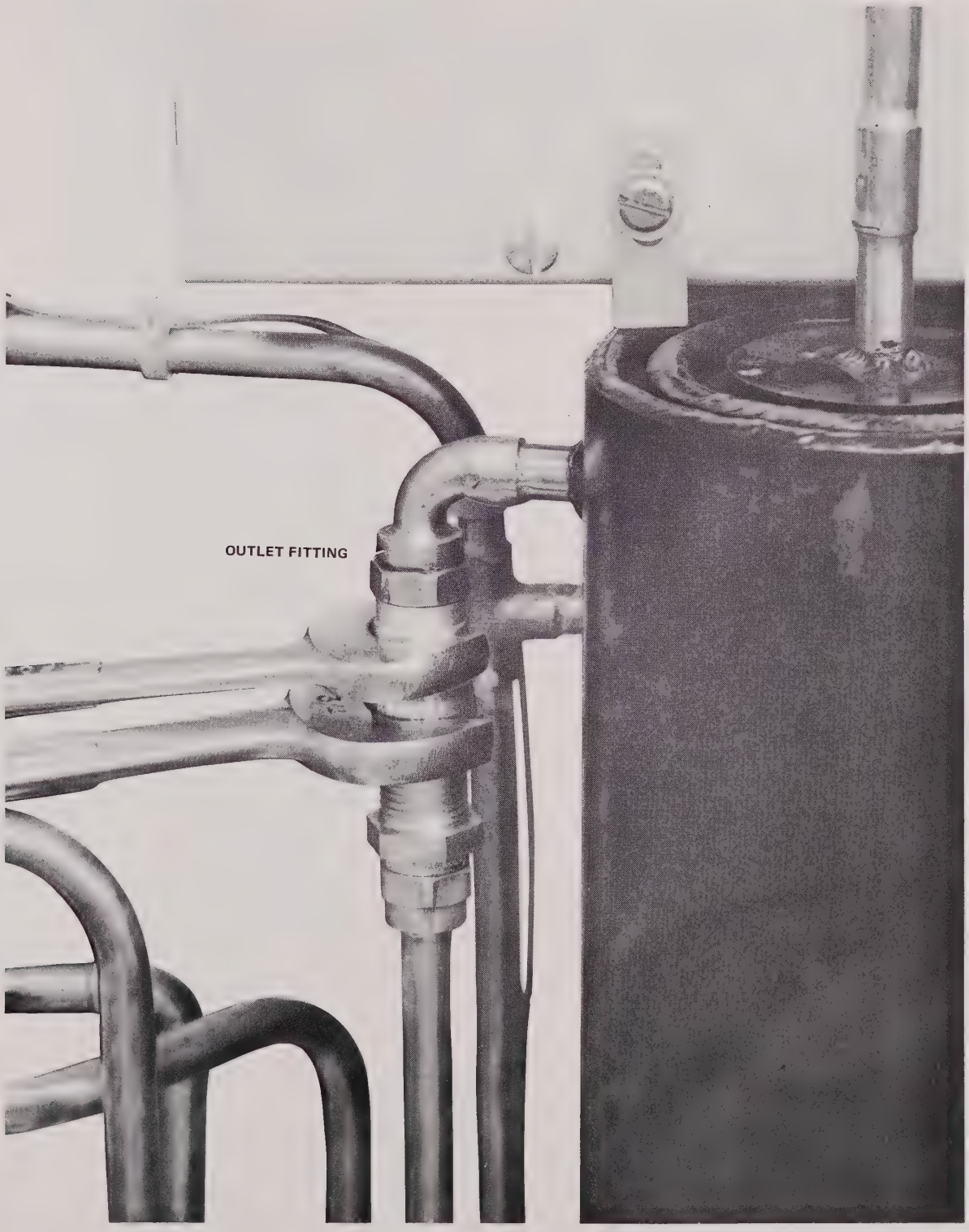
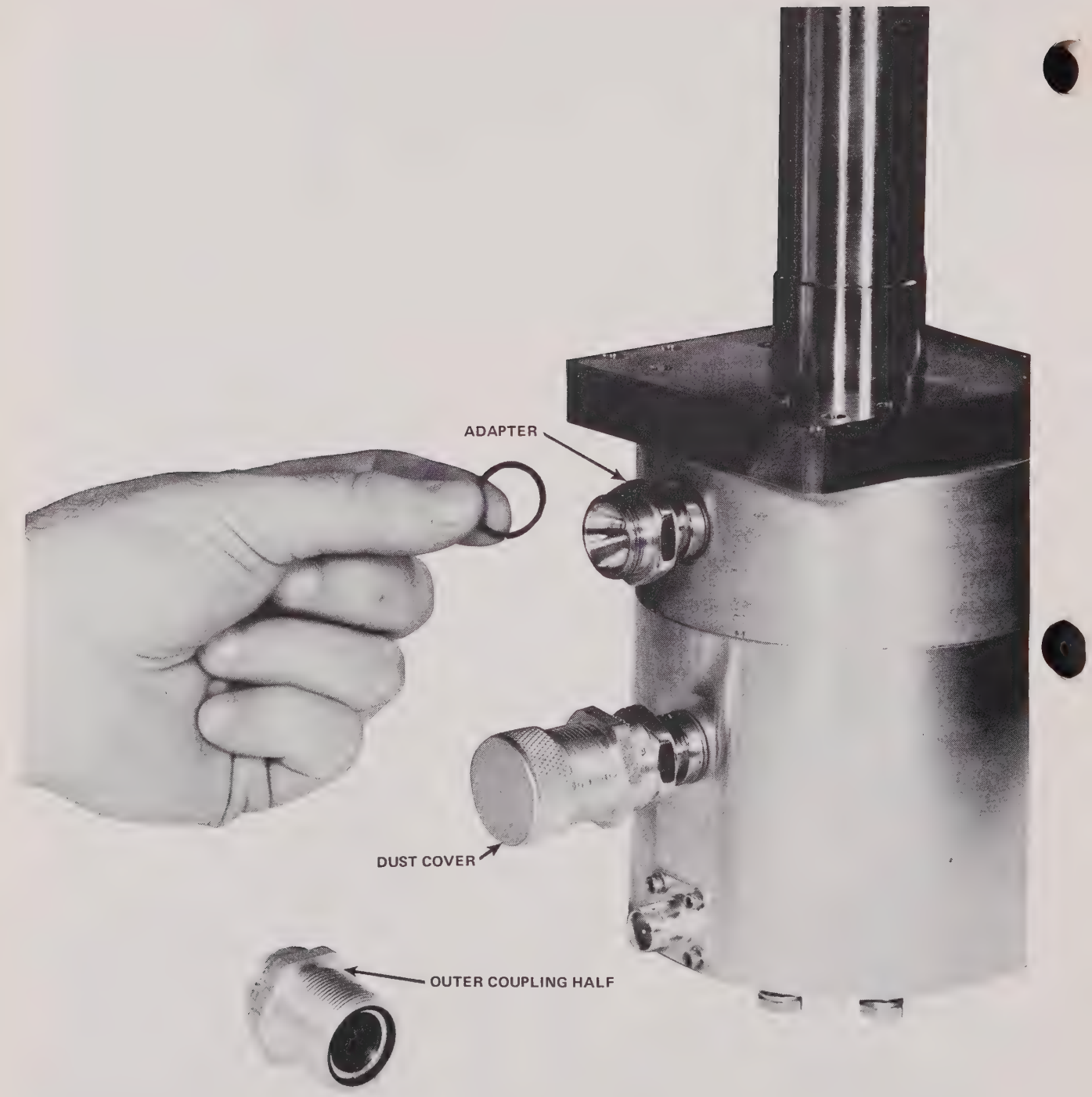


Figure 5-3 Adsorber Replacement


ADAPTER
DUST COVER
OUTER COUPLING HALF

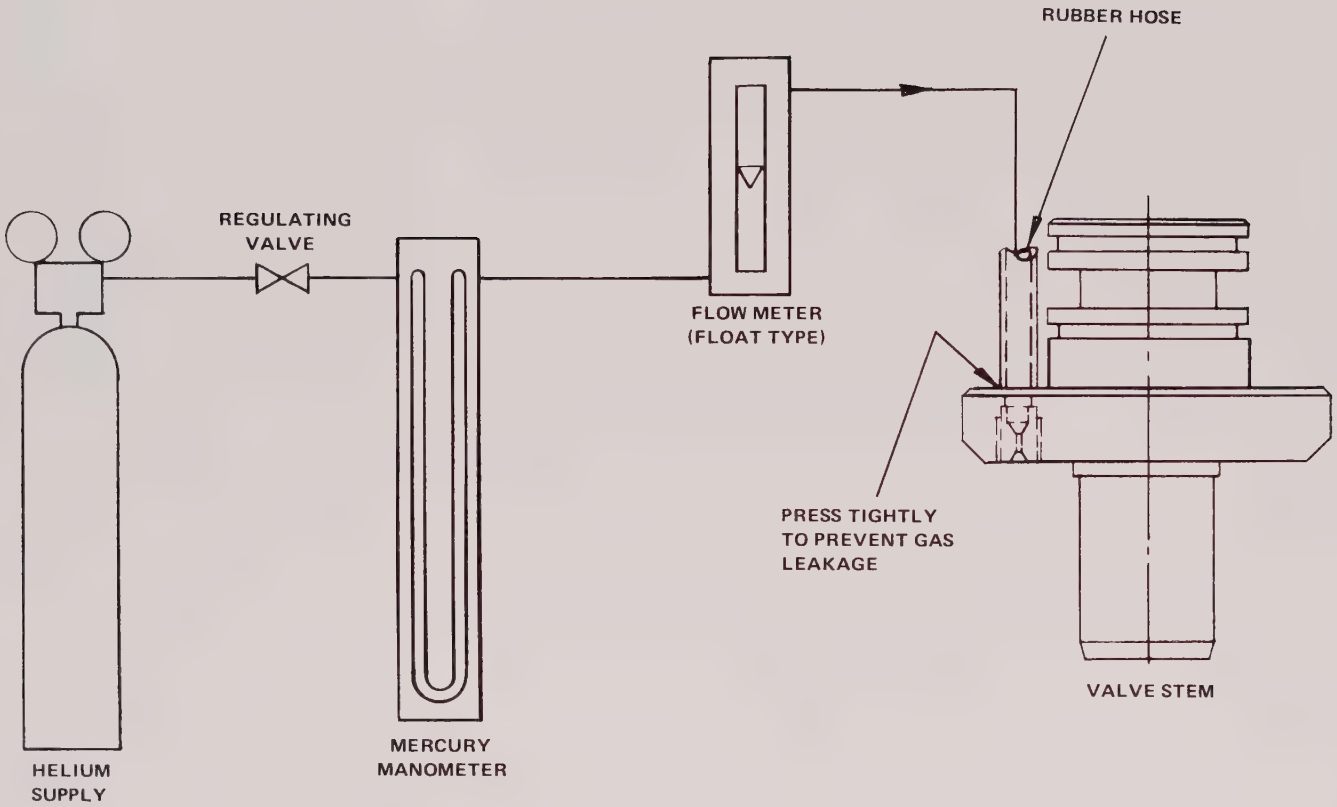
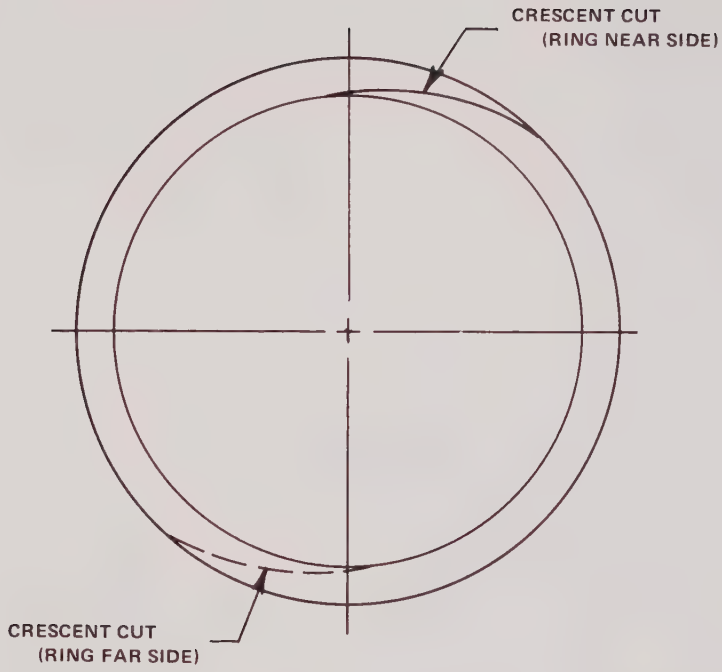


Figure 5-5 Measurement of Expander Orifice Flow



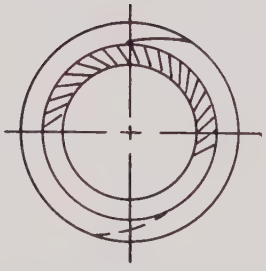


Figure 5-6 Displacer Warm and Cold End Seals

SECTION 6
DISPLEX CRYOPUMP SYSTEMS

This section covers all necessary aspects of Displex Cryopumps. The section is divided into four major subsections: Installation, Safety Aspects, Operation, and Maintenance. Figure 6-1 shows the basic cryopump design with the optional burst disc. This design is used as a building block for the other three standard cryopump designs. These designs are represented by an illustration of each design's basic dimensions (figures 6-2, 6-3 and 6-4) and by a photograph of each design (figures 6-5, 6-6, and 6-7).

NOTE

All preceding sections of this handbook also pertain to the cryopump system and should be read and understood before operation of the system. Inspection and installation of the system as described in Section 3 should be followed to insure proper operation.

6.1 INSTALLATION.

The following section describes the installation and setup.

6.1.1 Cryopump Installation Arrangements.

Figure 6-8 shows the three mounting arrangements that are most frequently used. These are characterized as:

a. INTERNAL. The refrigerator flange mates directly with the vacuum chamber and the cryopanels are in the main vacuum space.

b. APPENDAGE, OPEN. The spool piece flange, F_1, is mounted directly to the vacuum chamber without an intermediate valve.

c. APPENDAGE, VALVED. The spool piece flange, F_2, is mounted to a gate valve which can be closed to isolate the cryopump from the main chamber.

The cryopump can be mounted in any orientation. A chevron or a partial baffle can be attached to the warm panel of a bare pump if the heat load on the cold panel is found to be excessive. The characteristics of these arrangements as described in the next paragraphs apply to all size pumps with and without a chevron.

6.1.2 Installation Characteristics.

a. INTERNAL. The internal configuration will have the highest pumping speeds because inlet conductance losses can be minimized. This configuration also exposes the outside of the first stage cryopanel which has a large area. The outer surface is apt to become coated with H_2O which will absorb radiation and may overload the refrigerator. This can be avoided by wrapping the outside of the first stage cryopanel with about six layers of aluminized mylar or surrounding it with a highly polished spool piece simulator.

b. APPENDAGE, OPEN. Having the cryopump mounted in the spool piece provides shielding of the outside of the first stage cryopanel from H_2O and radiation. It shares with the internal pump the requirement that (1) the vacuum chamber be at a pressure of less than 10^{-2} torr in order for the pump to cool down, and (2) that total time to achieve a high vacuum is equal to the sum of the roughing time to 10^{-2} torr and the cooldown of the cryopump. If the cryopump is started at an initial pressure of 10^{-2} torr, then gases in the chamber are cryosorbed by the charcoal during cooldown and thus reduce the capacity for H_2 and He.

c. APPENDAGE, VALVED. This is the most commonly used configuration because it permits the cryopump chamber to be evacuated, the cryopump cooled down and/or maintained cold, and the cryopump regenerated, independent of the main vacuum chamber.

If the refrigerator is cold when the valve is opened to the main chamber, then the pressure in the main chamber can be greater than 10^{-2} torr. The maximum pressure that is permissible is a function of the conductance through the valve and the speed with which it is opened, the limiting factor being that the gas throughput cannot exceed the capacity of the pump.

As an example, a Model HV-202-6B Cryopump operating at 10^{-8} torr was connected by opening a gate valve to a 2.5 L chamber at 0.5 torr. The peak pressure recorded at the cryopump was 4×10^{-5} torr and the refrigerator warmed less than 1°K.

The user may want to try several different initial pressures and observe the temperature rise of the refrigerator. In general, if the refrigerator stays below 24°K (40 psia H_2), then the initial pressure is acceptable. This would not be true if the adsorbent material is retaining appreciable H_2 or He in which case the maximum temperature that could be tolerated is less than 18°K (7 psia H_2).

6.1.3 Mounting Cryopanels. When the cryopanels are shipped separately or after they have been removed to be cleaned, it is necessary for the user to mount them on the refrigerator. To get good thermal contact between the cryopanel and the refrigerator, a thin sheet of indium is placed between the two copper surfaces. It is important when tightening the mounting screws to feel the indium start to yield but not to overtighten to the extent that the indium starts to extrude from the joint. Indium gaskets can typically be reused four or five times.

When handling the crypanels, it should be remembered that fingerprints leave an oil film which results in that spot absorbing most of the incident thermal radiation. One should wear soft gloves or hold the panels with soft paper while mounting them. See figure 6-8 for parts breakdown.

Mounting of the cryopanels is straightforward if the following are remembered:

a. Always use an indium gasket.

b. Do not overtighten the mounting screws.

c. Avoid getting fingerprints on the cryopanels.

NOTE

If cryopump is being used to replace oil diffusion pump, insure that any oil residue is removed from gate valve.

6.2 SAFETY ASPECTS.

6.2.1 Gas Accumulation Limits. Cryopumps operate by freezing the gases that are pumped on the cold panel. These gases accumulate and are retained by the cryopump until the cryopanels are warned up. When the refrigerator is turned off, the cryopanels warm slowly and the pressure rises slowly until a pressure of 5×10^{-3} torr is reached, at which point convective heating becomes significant and the pressure rises rapidly as the retained cryodeposits evaporate.

WARNING

From a safety standpoint it is essential that the vacuum enclosure be designed to withstand a nominal internal pressure and that a pressure relief device be provided if there is a possibility that the pressure might exceed atmospheric pressure.

Units that have ASA flanges are typically used in the high vacuum range where the potential for accumulating appreciable quantities of gas exists. Because of this possibility, these units are all provided with a reseatable type pressure relief device. This valve is factory set to open at 5 psig and the system must be able to withstand 10 psig internal pressure.

Units with conflat flanges which are normally used in the ultra-high vacuum region where little gas is present are sold with the relief valve as an option. The optional metal diaphragm relief valve ruptures at 18 psig.

WARNING

It is important for the user to review the pressure rating of the vacuum system and set the relief valve to a lower pressure if necessary.

Tests have been run to determine what happens when large blocks of solid cryogen warm up. If the unit is mounted horizontally or cold end down the cryogen melts and spills onto the warm housing. Several hundred standard liters vaporize in less than a minute and are heard to vent for about 30 seconds. Peak pressure is several psi above the relief valve setting. The user should consider possible damaging effects of the cold cryogen spilling out of the cryopump. This can be avoided by orienting the cryopump cold end up.

It is also possible to vent the cryopump at a slower rate by pumping on it with a fore pump while it is warming. If the pressure can be maintained between 10^{-1} and 10^{-2} torr then the solid cryogen will sublime slowly. A foreline trap is needed to prevent oil back streaming from the pump.

The user can calculate how long it will take to accumulate enough gas for the pressure to reach 760 torr or warm up from the following equation. The operating time as a function of pump speed and enclosure volume is

$$t = \frac{V}{P \times S} \times \frac{760}{3600} \quad \text{(hrs)}$$

where

V = Volume, L
P = Pressure, torr
S = Speed, L/S

For example, if the HV-202-6 cryopump in the standard spool piece is sealed off by a gate valve, then it has a volume of 4 L. When pumping air, it has a speed of about 1,100 L/S, and for an operating pressure of 10^{-5} torr, it will operate for 77 hours before accumulating enough air to raise the pressure to one standard atmosphere absolute when it warms up.

Accumulation of air or argon is of primary consideration because the cryopump is capable of retaining an amount many times its volume, e.g., the HV-202-6 can retain more than 300 SL of air or argon. The adsorbed material is capable of retaining several liters of He and H_2, which also has to be considered.

6.2.2 Pumping Hydrogen. Studies on the combustion limits of hydrogen-air mixtures show that mixtures are flammable over a wide range of concentrations and down to a pressure level of about 10^{-1} torr. The energy required for ignition is also very small, less than a millijoule. While these components are adsorbed the adsorbent acts as a diluent, thus the hazard exists only when a system is being warmed up and they are present in the gas phase. The worst situation is probably one in which hydrogen is the primary gas being pumped, such as accelerator beam lines, and there is a rupture in the vacuum vessel. This problem has been considered by Pittinger [1] and his recommendation is contained in the following warning.

WARNING

The amount of hydrogen in the

WARNING (cont.)

system should be less than 12 TL (1.6 SCC) per L of system volume to stay below the combustion limit.

If one considers only the problem of keeping the pressure below one atmosphere then a limit of 25 TL (33 SCC) per L of volume can be used as a guide.

2.3 Pumping Pure Oxygen. Oxygen is normally pumped on the outside bare surface of the cold panel, however, some of it does migrate to the charcoal adsorbent on the inside of the cold panel. Liquid oxygen-carbon mixtures have been used in the mining industry as an explosive [2]. The principal characteristic of this mixture from a safety standpoint is that it requires a large amount of energy to ignite it, e.g., a blasting cap. In order to avoid this potential hazard APCI does not mount electrical leads near the charcoal surface. This point is emphasized in the following warning.

WARNING

Never run electrical leads, such as heater leads, near the charcoal adsorbent on the cold panel.

[1] Pittinger, L.C. "Large-Scale Cryopumping for Controlled Fusion," Lawrence Livermore Laboratory preprint UCRL-79381 presented at 1977 Cryogenic Engineering Conference. *Advances in Cryogenic Engineering* Vol. 23, Plenum Press, N.Y. 1978.

[2] Tournay, E.E., Bower, F.M., and Brown, F.W. "Safety and Performance Characteristics of Liquid Oxygen Explosives," U.S. Dept. of Interior, Bureau of Mines, Bulletin 472, U.S. Government Printing Office, Washington, D.C., 1949.

6.3 OPERATION.

6.3.1 Cooldown. In order for the refrigerator to reach minimum temperature the vacuum must be adequate to eliminate convective heating. This means that a pressure of less than 2×10^{-3} torr is necessary. It has been demonstrated that the cryopump can start with initial pressures in excess of 1×10^{-2} torr. This is possible because the adsorbent material pumps the residual water and air at a relatively high temperature (150°K). The pump thus creates its own insulating vacuum. It should be remembered that the gases that are adsorbed reduce the capacity of the adsorbent material for He and H_2; thus, if the pump is being used for pumping these gases, a lower initial pressure is recommended.

When a pump is initially installed, the charcoal on the second-stage cryopanel will have a high outgassing rate because of its exposure to air during installation. It is therefore necessary to rough pump the cryopump for a period of 8-12 hours before starting the system. This procedure applies whenever the cryopump is exposed to atmospheric pressure.

In using the pump in the valved appendage mode the vacuum volume surrounding the pump must be minimized during the cooldown, i.e., close both rough and gate valves. This operating procedure will insure maximum quantities of chamber evacuation between regenerations.

Cooldown time is basically a function of refrigerator capacity and the mass of the cryopanels. It will vary from about one hour for the 6" size pump (without chevrons) to several hours for larger pumps. Cooldown time is extended slightly if the initial pressure is greater than 2×10^{-3} torr.

6.3.2 Steady State. The accumulation of cryodeposits is accompanied by either or both an increase of partial pressure of the gas and an increase in cryopanel temperature. Helium and hydrogen which are adsorbed do not result in a heat load, but they do result in an increase in partial pressure as they are adsorbed. Water, on the other hand, does not contribute to an increase in its partial pressure as it accumulates but it does represent a large heat load.

Air and argon have the combined characteristics of both increasing in partial pressure and increasing the heat load as they accumulate.

During steady state operation both the pressure and second-stage temperature should be monitored. Chamber pressure should be maintained below 2×10^{-3} torr in order to prevent convection heating from causing a warmup. The second stage temperature should be kept below 30°K if there are only trace quantities of He and H_2. If H_2 is the primary gas being pumped, then it is desirable to maintain the minimum temperature possible.

It is generally desirable to have the refrigerator operate at the minimum possible temperature. Since absorptance of thermal radiation by cryodeposits (especially water vapor) is the primary cause of thermal loading of the cryopanels, the following steps can be taken to minimize this:

a. Maintain a clean, highly polished vacuum chamber.

b. Interpose a baffle, preferably black and water-cooled, between a high-temperature heat source and the cryopump.

c. Add a partial deflector, or for heavier water loads, a chevron baffle, attached to the warm (80°K) stage to shield the cold stage.

6.3.3 Power Interruptions. In most applications the user will establish an upper temperature limit of operation, at which time the pump should be regenerated. One of the principal factors in setting the temperature limit will be the "coast" time of the cryopump. This is the time it takes for the pump to warm up and release enough gas to break the insulating vacuum after the power is turned off. If the power comes back on after an interruption during the coast period, then the cryopump will recover. If the coast period is exceeded, the cryopump will not recover.

Cryopumps that are operating at less than 14°K have such a low level of heat input that the refrigerator can be off for a period of up to five minutes before it warms to the point where it releases cryodeposits of air. If the refrigerator is operating at a higher temperature, it has a higher heat load and thus will warm up faster. If He or H_2 is present, they may be released before the air and result in a shorter coast period.

6.3.4 Regeneration. When the pump is turned off and vacuum is broken by the release of cryodeposits, the panels warm very quickly to 100°K, then as the specific heat of the metal increases the warming rate decreases. If one wants to remove only the air and "noncondensables", then evacuation while the panels warm to 150°K is adequate before restarting the refrigerator. Regeneration and cooldown back to minimum temperature can typically be accomplished in about 30 minutes.

If water vapor is to be removed, then the cryopump must be warmed to room temperature. This is most easily done by having the pressure be greater than 10^{-2} torr and allowing heat to flow from the enclosure walls to the cryopanels by convection. Evacuation with a forepump for a period of four to twelve hours is usually adequate to regenerate the panels.

The cryopanels and refrigerator can tolerate a maximum temperature of 100°C. For applications in the ultra-high vacuum region, it is usually desirable to heat the chamber to 100°C during the regeneration period to help drive off residual water vapor.

6.3.5 Failures, Unplanned Shutdowns and Upsets. This section is basically a trouble-shooting guide for those times when the system malfunctions during operation, does not start, or an unplanned shutdown occurs. The interest here is to generalize on the description of potential problems and thus encompass many corrective action procedures. This will allow prompt correction by the customer in the field.

Table 6-1 contains a list of problems, possible causes, and corrective action which may be encountered when operating the Displex Cryopump Systems. The possible causes and corrective actions listed in the table are shown in the order of increasing severity; thus, the user should investigate the possible cause in the order in which they are listed.

See Tables 4-1, 4-2, and 4-3 for trouble-shooting the compressor and expander module.

6.4 MAINTENANCE.

6.4.1 Maintenance Procedures for expander and compressor module are described in Section 5.

There is no planned maintenance required on the cryopanels; however, if oils or other contaminants have gotton onto the panels that cannot be removed by pumping, then the panels should be removed and cleaned. DuPont Freon TMC solvent is recommended for cleaning the cryopanels including the painted area and if necessary, the adsorbent surface can be rinsed in it. Stronger cleaning agents that will attack the epoxy paint should be avoided. A soft cloth should be used to wipe off the panels in order to maintain the high polish.

After cleaning the adsorbent surface with a solvent, a vacuum bakeout for several hours at 100°C is recommended. Evacuation for about an hour at room temperature is adequate for bare surfaces that have been cleaned.

TABLE 6-1
CRYOPUMP TROUBLESHOOTING GUIDE

Problem	Possible Causes	Corrective Action
1. Expander gets cold but system will not pump down.	(a) Valve to roughing pump not closed completely.	(a) Correct as required.
	(b) Vacuum leak in system (small).	(b) Leak check and repair as required.
	(c) Cryopanels not secured.	(c) Tighten as required.
2. Expander will not get cold.	(a) Valve to roughing pump not closed.	(a) Correct as required.
	(b) Vacuum leak in system.	(b) Leak check and repair as required.
	(c) Panels overloaded.	(c) Regenerate system.
	(d) Residue on cryopanel causing high radiation load.	(d) Remove panel and clean per section 6-3.
	(e) Thermal short of first stage cryopanel to warm pump enclosure. Cold or frost spot on pump enclosure.	(e) Correct as required.
	(f) Oil contamination on panels; check for back streaming from mechanical rough pump.	(f) Clean and bake out panels per section 6-4 Note: It is good practice to include a dry trap between the mechanical and cryogenic pump.

See tables 4-1, 4-2 and 4-3, Troubleshooting Guides for expander and compressor.

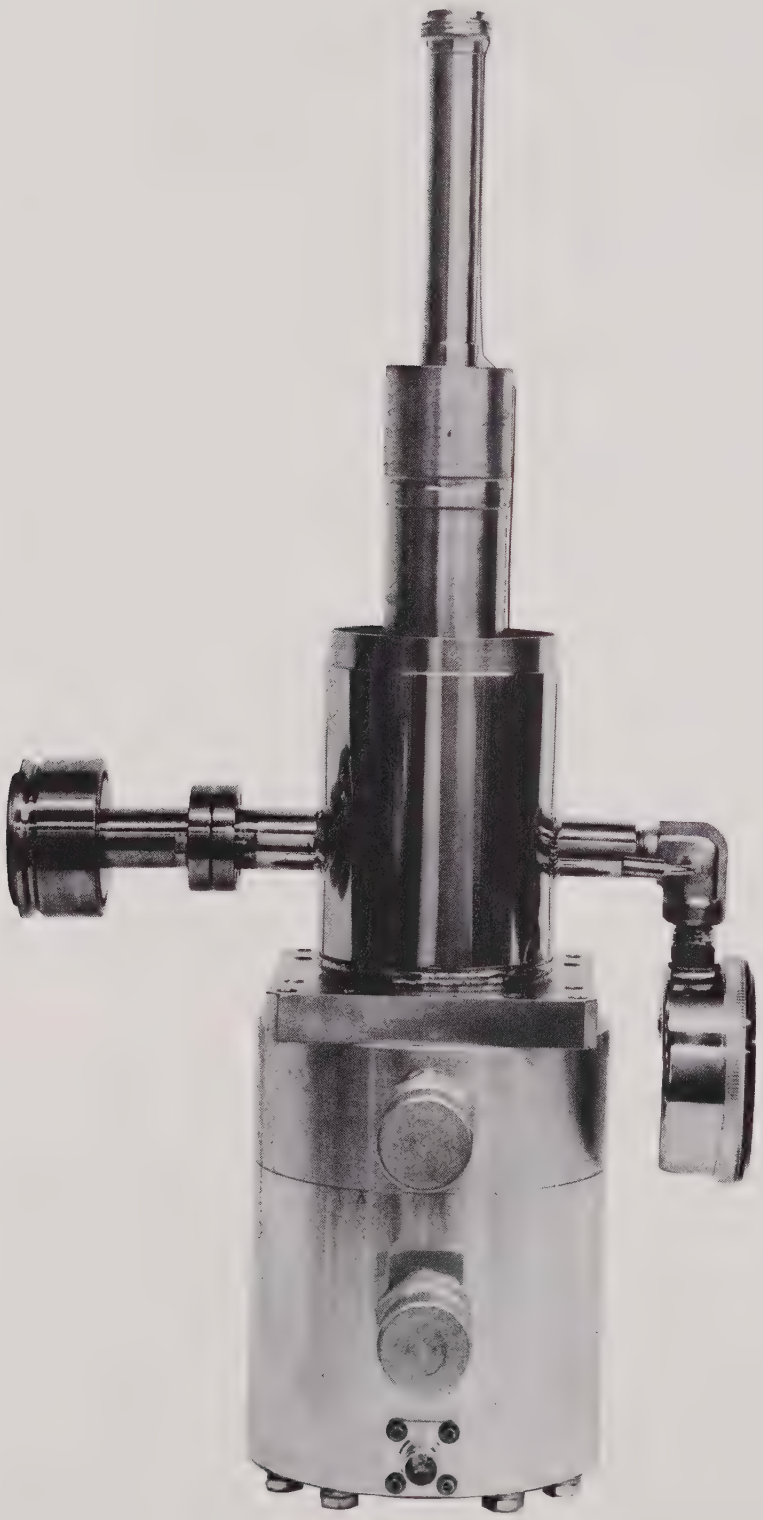
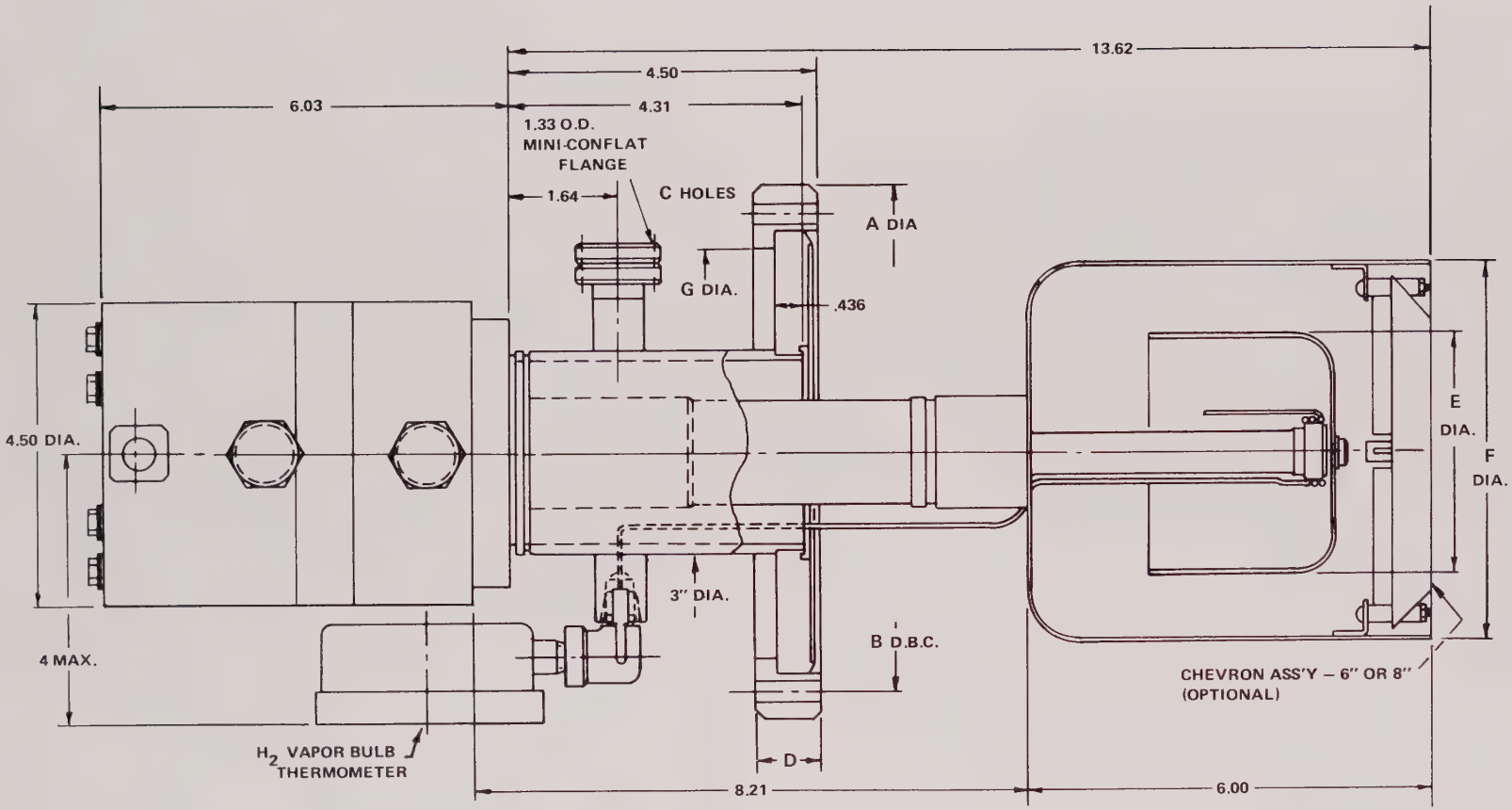
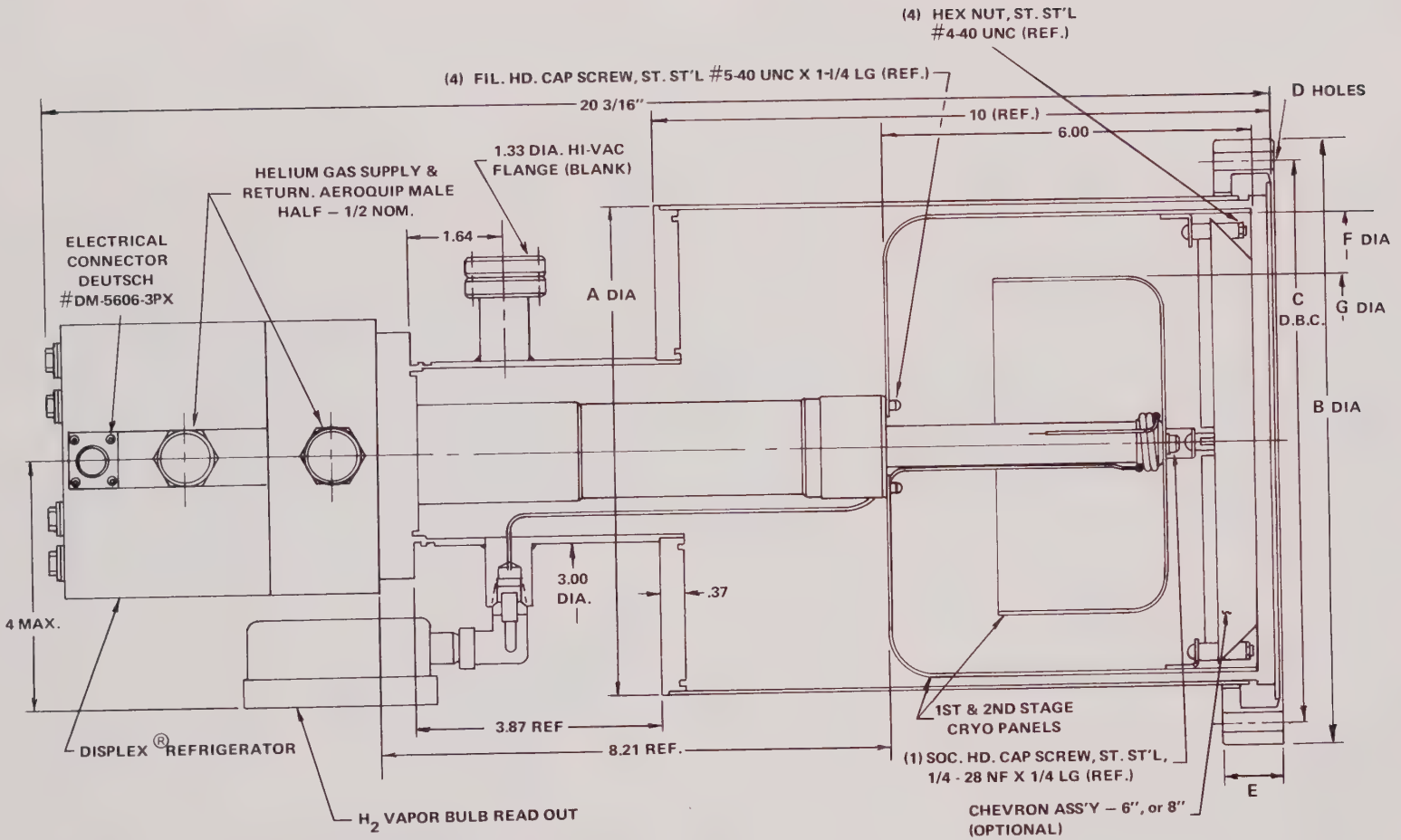


Figure 6-1 Displex Expander Less Pump Enclosure and Panels



SIZE REFERENCE CHART								
NOM PUMP SIZE	A DIA	B D.B.C.	C		D DIM	E DIA	F DIA	G DIA
			DIA. HOLE THRU	NO. HOLES				
6"	7.97	7.128	.332	20	.93	3.50	5.55	6.125
8"	9.97	9.128	.332	24	.97	5.50	7.55	8.125

Figure 6-2 HV-202-6, 8 Cryo Pump


(4) HEX NUT, ST. ST'L #4-40 UNC (REF.)
(4) FIL. HD. CAP SCREW, ST. ST'L #5-40 UNC X 1-1/4 LG (REF.)
20 3/16"
10 (REF.)
6.00
D HOLES
1.33 DIA. HI-VAC FLANGE (BLANK)
HELIUM GAS SUPPLY & RETURN. AEROQUIP MALE HALF – 1/2 NOM.
1.64
ELECTRICAL CONNECTOR DEUTSCH #DM-5606-3PX
A DIA
F DIA
C D.B.C.
G DIA
B DIA
3.00 DIA.
.37
4 MAX.
3.87 REF
8.21 REF.
1ST & 2ND STAGE CRYO PANELS
(1) SOC. HD. CAP SCREW, ST. ST'L, 1/4 - 28 NF X 1/4 LG (REF.)
E
DISPLEX® REFRIGERATOR
H_2 VAPOR BULB READ OUT
CHEVRON ASS'Y – 6", or 8" (OPTIONAL)

SIZE REFERENCE CHART								
NOM. PUMP SIZE	A DIA	B DIA	C DBC	D DIA - THRU	D NO. HOLES	E	F DIA	G DIA
6"	6"	7.97	7.128	.332	20	.93	5.53	3.53
8"	8"	9.97	9.128	.332	24	.97	7.53	5.53

Figure 6-3 UHV-202-6, 8 Cryo Pump

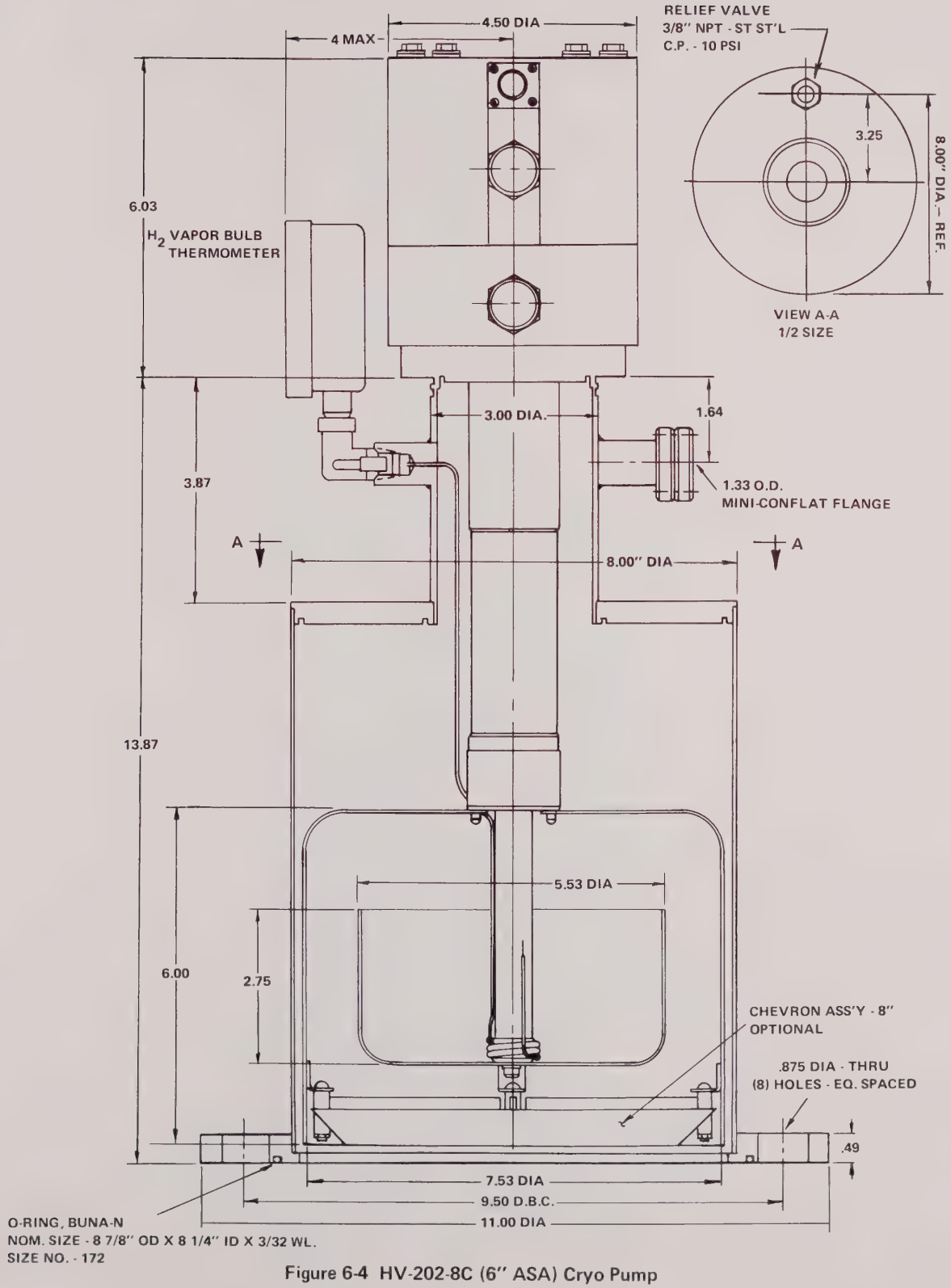


Figure 6-4 HV-202-8C (6" ASA) Cryo Pump

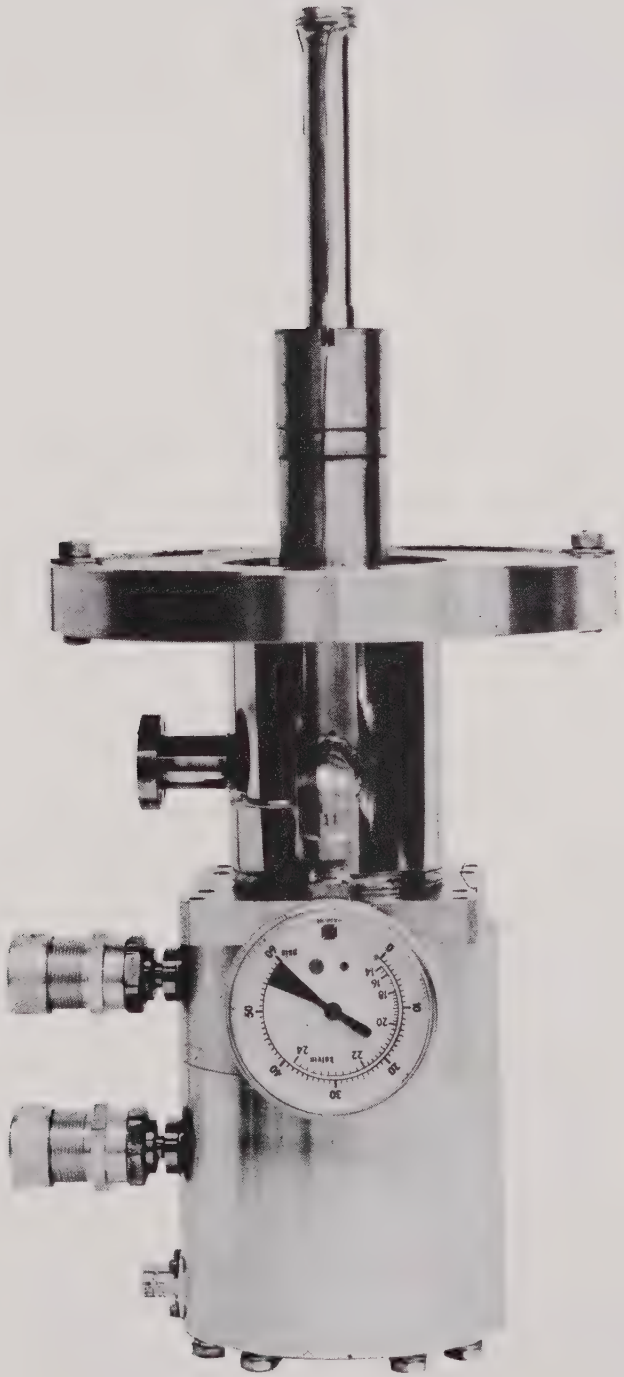


Figure 6-5 Displex Expander With 6" x 8" Conflat Flange

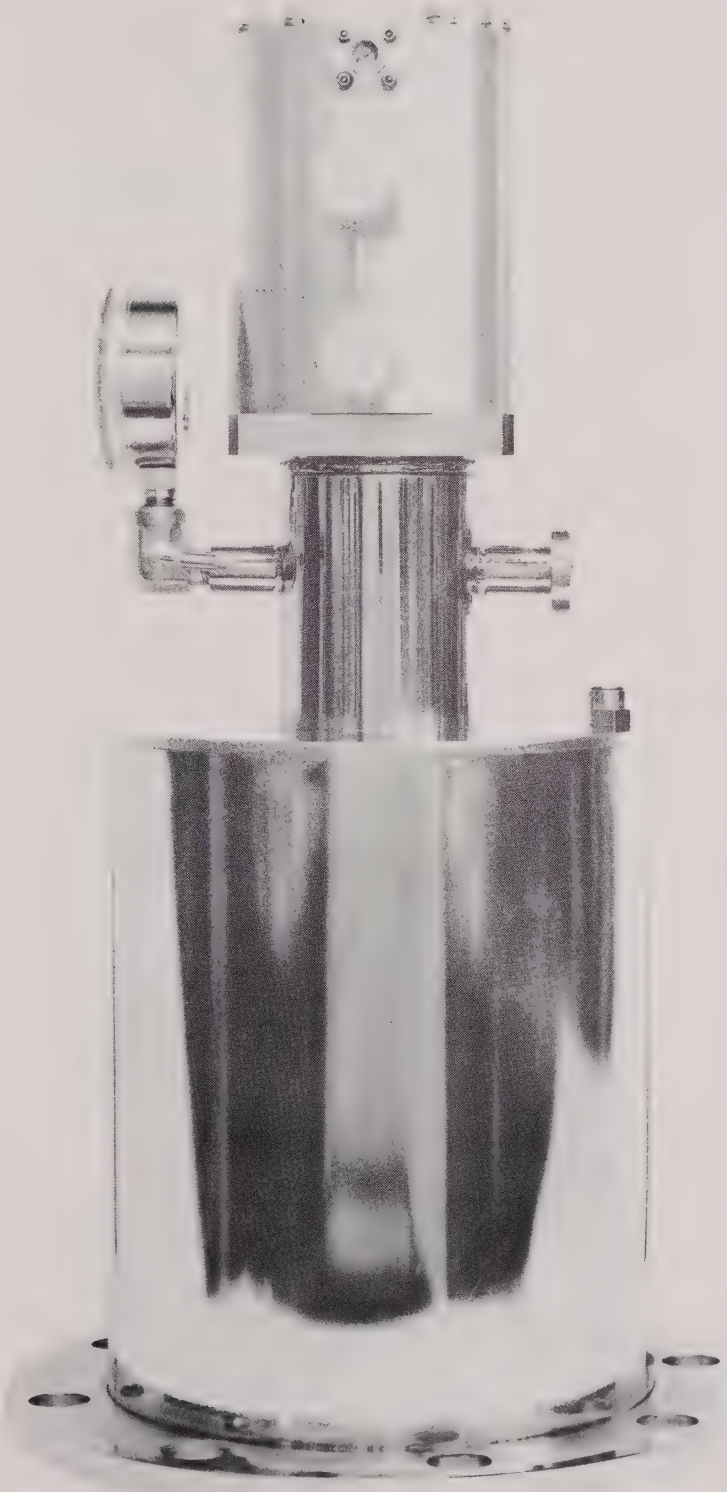


Figure 6-6 Displex 6" ASA Pump

Figure 6-7 Displex Conflat Configuration Pump

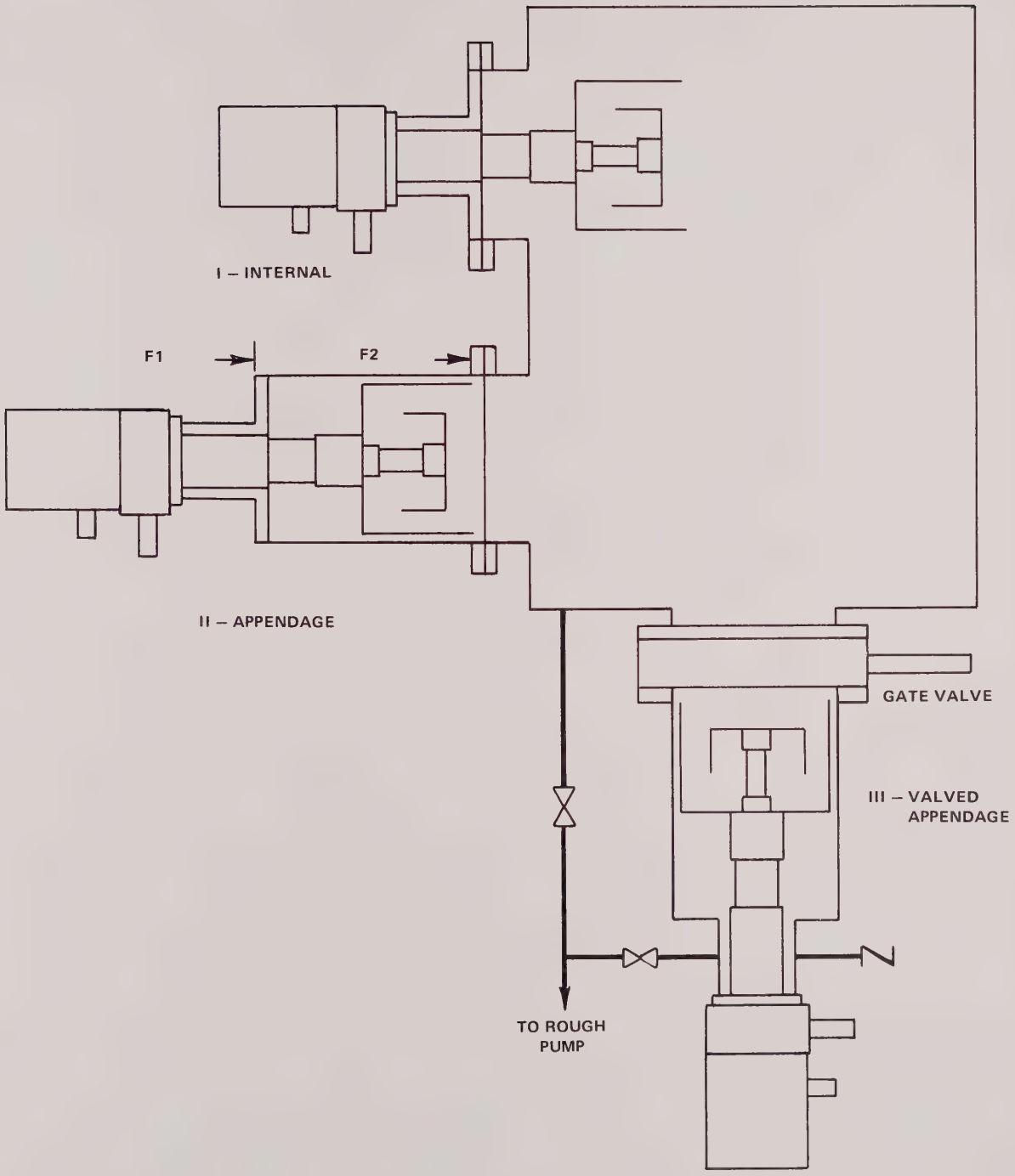


Figure 6-8 Cryo-Pump Mounting Arrangement

SECTION 7
INTERFACE ARRANGEMENTS

This section contains installation and maintenance information pertaining to interface arrangements that are supplied with Displex® refrigerator systems for research applications. The Displex system is most commonly used as an accessory to cool a sample, specimen, detector, or other object requiring operation at cryogenic temperatures. Operation at cryogenic temperatures requires an insulating vacuum surrounding the specimen area and generally a radiation shield around the second stage of the refrigerator. In addition, there may be provisions for electrical- and temperature-sensing feedthroughs on the expander assembly.

7.1 VACUUM SHROUDS.

Figure 7-1 shows two typical vacuum shrouds. These are connected to the expander assembly by the use of a double O-ring seal (reference Figures 3-4 and 3-5). The internal surface of the shroud is specially machined to provide a sealing surface and the proper compression of the O-rings to hold the shroud in place when the refrigerator is placed in the vertical position. Vacuum grease should be used on these O-rings for best results in holding a good vacuum seal.

The basic expander assembly may be equipped with an integral skirt or may simply have a flat flange without any feedthrough provisions or method for mounting vacuum shrouds. Generally most systems are supplied with an integral skirt. All of the skirts have a ¾'' O.D. tube extending approximately 3½'' out from the skirt. This is for evacuation of the vacuum space after the vacuum shroud is installed.

7.2 RADIATION SHIELDS AND SAMPLE HOLDERS.

Most systems, where the objective is the cooling of a small specimen for the purpose of subjecting the sample to a radiation or magnetic environment, require a radiation shield around the second stage. This shield generally has access holes for a clear view into the sample area. The shape of these holes is tailored to the shape of the sample holder. If it is required that holes be drilled in the radiation shield by the customer it should be placed on a precision support rod, termed a mandrel, to prevent distorting or tearing the thin walls when drilling. Some portion of this mandrel will then be machined away when drilling the holes. The radiation shield serves two basic purposes. It shields the second stage from direct thermal radiation and cryopumps the sample region, thus reducing contamination. Figure 3-5 shows the mount for the radiation shield. This mount has external threads onto which the radiation shield is turned. When installing the shield, make certain the shield is completely bottomed on these threads. A slight amount of vacuum grease on these threads is helpful. With the shield bottomed on the mount, it may be necessary to back off less than one turn in order to align the holes in the shield with the sample holder.

All of the sample holders supplied by APCI are mounted in the same manner — that is, with the use of a ¼-28 UNC copper mounting stud. This threads into a mating female mounting hole in the bottom of the second stage of the refrigerator. When mounting the sample holder, it is best to use a thin sheet of indium (approximately 0.005 thick) between the sample holder and the expander cold tip.

NOTE

Do not overtighten the sample holder. Use no tools. Hand tighten only.

The following two guidelines should be followed if the user designs and fabricates his own sample holder:

(1) Use only OFHC (Oxygen-Free High Conductivity) Copper.

(2) Threaded stud must be ¼-28 UNC thread size, with a maximum thread length of ¼".

7.3 INSTRUMENTATION.

The options on the DE-202 expander for instrumentation and temperature control are quite varied. Generally these options can be thermocouple(s), a heater, resistance or diode temperature sensors, a hydrogen vapor bulb thermometer, and a variety of electrical leads for special customer requirements. All instrumentation leads are heat stationed, tempered, by wrapping the leads around the cold tip and first stage heat station.

The thermocouple option supplied with the system is a Chromel P vs. Gold +.07 atomic % iron type. This is generally indium soldered to the second stage heat station. When making a thermocouple junction with the chromel and gold wire, two precautions must be observed.

NOTE

When attaching Au.Kp thermocouples

a. Use only indalloy No. 1 solder from the installation kit. Do not use a solder which contains lead.

b. Do not overheat the wire when soldering, as the gold will burn away.

It is best to tin both wires before forming the junction. Appendix D shows the proper method for connection of the thermocouple ice junction and readout.

The heater supplied with the system is the 46 ohm, foil strip heater attached to the second stage tip on the expander. This heater consists of a fine, high-resistance printed circuit in a mylar film. The differential thermal stresses between the mylar and the copper heat station result in the heater having an estimated life of about a thousand cycles from cryogenic to ambient temperature.

Thermal bonding of the heater to the cold tip is achieved by a tight overwrapping of mylar thread. Nylon shrinks more than mylar and copper as it gets cold, thus the contact pressure on the heater increases to enhance heat transfer.

The types of sensors supplied with the Displex system depend on the type of controller or readout that is to be used. In general, the type of sensors available are Platinum and Germanium Resistance Thermometers and Silicon and Gallium Arsenide Diodes. More specific data on the sensors is supplied with the temperature controller.

When a hydrogen vapor bulb thermometer is part of the system, this is mounted by threading a fitting into a receptacle welded to the skirt. This joint forms a gastight seal between hydrogen and the atmosphere. Initially the thermometer is charged to 57 psia. The bulb will be effective down to a point where this charge is within the green region on the gauge. Below this the system should be recharged. It is recommended to return the unit to the factory for the maintenance. A vapor pressure curve showing the relationship between hydrogen pressure and temperature is shown in Appendix D.

7.4 FEEDTHROUGH.

The vacuum feedthrough most commonly used for heater and thermocouple leads consists of a drilled Teflon insert which is compressed inside of a Gyrolok fitting. This is illustrated in Figure 7-2. If a vacuum leak is suspected, the tightness of the connection should be checked. Turning by no more than 2 or 3 flats on the compression nut will improve the seal.

The electrical feedthrough shown in Figure 3-5 consists of a Deutsch receptacle DM5605-12P and O-Ring. The O-Ring forms a vacuum seal behind the hermetic receptacle. This O-Ring is a Parker 2-19 or equivalent. The electrical receptacle has 12 pins which are used for sensors and heater leads. In all cases the mating Deutsch plug DM-9702-12S is supplied; however, if a controller is supplied as part of the system the plug is installed on a cable assembly to provide a link between the expander and controller. In high vacuum applications an 8-tube-high vacuum feedthrough is available as an option. This is mounted on a 1.33 O.D. high vacuum flange and a copper gasket is used as a vacuum seal.

7.5 EXPANDER TIP HEATER REPLACEMENT.

The following procedures are a guide to replacing the heater without a great deal of specifics. Generally the user has his own preference for methods of mounting instrumentation.

a. Carefully unsolder the thermocouple cold junction and unwind that portion of the thermocouple which is laid over the heater. If your system is not fabricated this way, then disregard. It is only necessary to remove the thermocouple if it is wrapped over the heater.

b. Cut the nylon ties which hold the outer copper sheath over the heater. Remove the nylon and copper sheath.

c. Remove the heater leads (2) where they are spliced to the permanent wires. Generally, the heater heads have red insulation and the permanent wire blue.

d. Remove the heater. A dark spot anywhere on the heater is a visual indication of failure.

e. Thoroughly clean the surface where the new heater is to be installed.

f. Wrap the heater, overlay with the copper sheath and tie. See Figure 7-3.

g. Splice in the new leads to the permanent wires. Install sleeving at the splice.

h. Re-wrap and solder the thermocouple.

i. Check the heater resistance at the room temperature connections. This value should be 46.5 ohms $\mp$ 5%. Also check resistance to ground. This should be a very large value.

In general, heater failures can be avoided by operating the heater at values less than maximum rating, which is 20 watts. For use with the Displex system, heat inputs of 10 watts or less should be sufficient for all cases. Under all circumstances, avoid operating the heater when the tip is at or near room temperature, and an insulating vacuum is in effect around the expander.

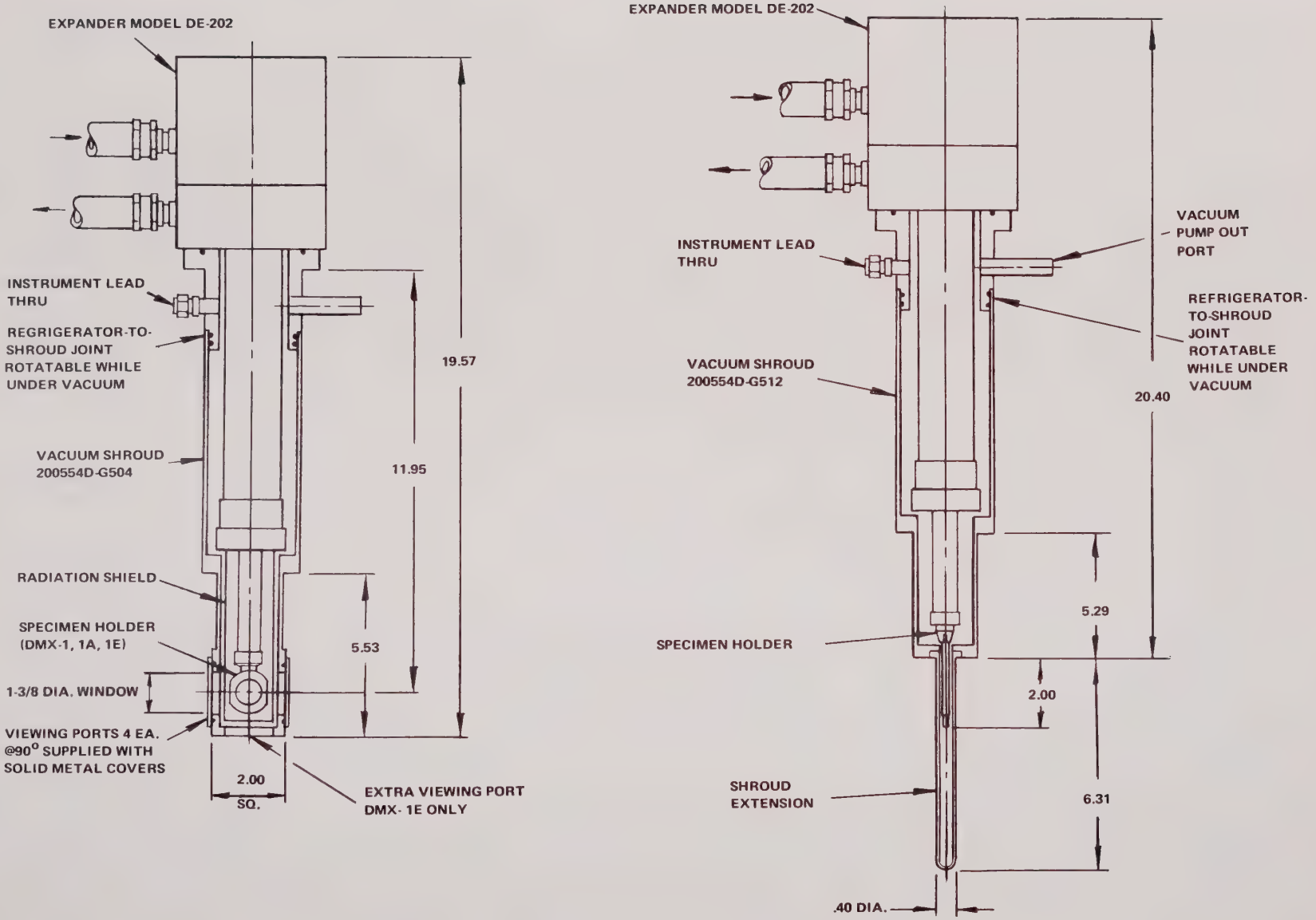


Figure 7-1 Two Typical Vacuum Shrouds for the DE-202 Expander

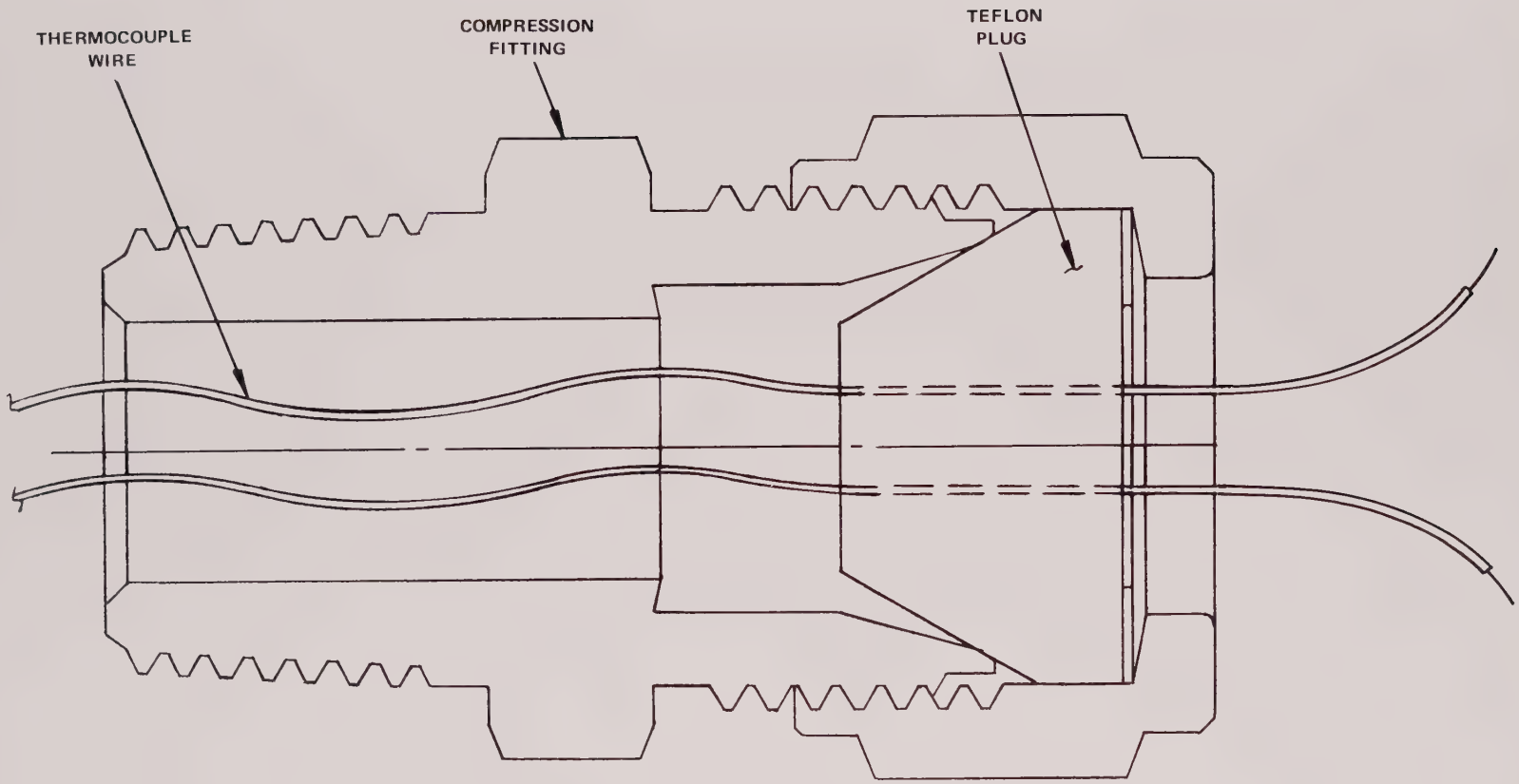


Figure 7-2 Vacuum Feedthrough Using A Compression Fitting

APPENDIX A: SPARE PARTS LISTS

TABLE A-1
PARTS LIST FOR COMPRESSOR MODULE MODEL 1L02W
Reference Figure A-1 (a) and (b)

Item	Qty.	APCI Part No.	Description
1	1	201323E-G502	Base, Front & Rear Panels
2	1	201324D	Cover
3	1	251222C	Compressor Assembly Water Cooled 230V
4	1	201076C-G503	Oil Separator Assembly
5	1	202530C	Adsorber Assembly
6	1	250392D	Electrical Box Assembly
7	REF	250389D	Wiring Diagram
8	1	201100B	Cable Assembly "D-1"
9	1	201101B	Cable Assembly "D-2"
10	1	201326A	Bracket, Pressure Switch
11*	1	86619B	Nameplate
12	1	(39800)	Solenoid Valve
13	1	(38700)	Pressure Switch
14	4	251226A-16	Mounting Pads
15	2	(53206)	Valve, Needle, Globe, Panel Mount
16	2	(50500)	Gauge, Panel Mount 2" Dial Size
17	1	(53403)	Relief Valve
18	1	(01800)	Bulkhead Adapter
19	1	(01700)	Bulkhead Adapter
20	1	(14600)	Connector Female
21	1	(15200)	Connector Female
22	2	(15000)	Connector Male
23	2	(15008)	Connector Male
24	8 ft	251226A-35	Tubing Copper
25	8 ft	251226A-36	Tubing Copper
26	10 ft	251226A-37	Tubing Copper
27	2	(47501)	Tubing Adapter
28	2	(44701)	Coupling Half
29	2	(46401)	Lock washer
30	2	(46101)	Jam Nut
31	2	(47101)	Adapter O-Ring
32	2	(45301)	Dust Cap
33	2	201486A	Connector Orifice
34	1	251226A-50	Connector Cable
35	1	251226A-51	Connector Cable
36	2	251226A-52	Connector Cable
37	1	(52801)	Valve Relief
38*	1	251226A-82	Grommet
39*	1	201513A	Displex Installation Kit

*Not shown on Figures

TABLE A-1 (cont.)

Item	Qty.	APCI Part No.	Description
40	4	251226A-85	Caster Swivel
41*	1 qt	251226A-88	Lubricating Oil UCON-LB-300X
42	2	(44601)	Coupling Half
43	2	(47401)	Tubing Adapter
44	2	(47001)	O-Ring
45	12 ft	251226A-96	Tubing Copper
46	1	(39200)	Temperature Switch
47	1	(33100)	Spring Clip
48	1	(37100)	Over load, Heater Relay

*Not shown on Figures

TABLE A-2
PARTS LIST FOR COMPRESSOR MODULE 1L02A
Reference Figure A-2 (a) and (b)

Item	Qty.	APCI Part No.	Description
1	1	201323E-G501	Base Front & Rear Panels
2	1*	201324D	Cover
3	1	201354C	Compressor Assembly
4	1	201076C-G503	Oil Separator Assembly
5	1	202530C	Adsorber Assembly
6	1	96578C	Condenser
7	1	96924A	Specification for Lubricating Oil Pump
8	1	201355C	Heat Shield
9	1	250392D	Electrical Box Assembly
10	1	201100B	Cable Assembly "D-1"
11	1	201101B	Cable Assembly "D-2"
12	REF	290389D	Wiring Diagram
13	1	201326A	Bracket, Pressure Switch
14	1	86619B	Nameplate
15	2	201486A	Connector Orifice
16*	1	201512A	Displex Installation Kit
17	1	(35400)	Fan Motor
18	1	201353A-25	Fan Blade
19	1	201353A-26	Fan Motor Mounting Bracket
20	1	201353A-27	Fan Shroud
21	2	201353A-28	Sheet Metal Clips (Shroud to Bare)
22	2	201353A-29	Wire Clips (Shroud to Condenser)
23	1	201353A-30	Nut (Fan to Motor)
24	4	201353A-31	Mounting Pads
25	1	(38700)	Pressure Switch
26	2	(53206)	Valve Needle
27	2	(50500)	Gauge, Panel Mount, 2" Dial Size
28	1	(52801)	Valve, Relief
29	2	(47501)	Tubing Adapter
30	2	(44701)	Coupling Half
31	2	(46401)	Lockwasher
32	2	(46101)	Jam Nut
33	2	(47101)	Adapter O-Ring
34	2	(45301)	Dust Cap
35	8 ft	201353A-47	Tubing Copper
36	7 ft	201353A-48	Tubing Copper
37	18 ft	201353A-49	Tubing Copper
38	1	(53630)	Valve, Check

*Not shown on Figures

TABLE A-2 (cont.)

Item	Qty.	APCI Part No.	Description
39	1	201353A-67	Connector, Cable Strain Relief
40	1	201353A-68	Connector, Cable Strain Relief
41	1	201353A-69	Connector, Cable Strain Relief
42	1	201353A-71	Knockout Seal
43	1	201353A-72	Knockout Seal
44	1	201353A-95	Lock nut
45*	1 qt	201353A-99	Lubricating Oil UCON -LB-300X
46*	1	201353A-100	Grommet
47	4	201353A-103	Caster Swivel
48	2	(44601)	Coupling Half
49	2	(47401)	Tubing Adapter
50	2	(47001)	O-Ring
51	18 ft	201353A-114	Tubing Copper
52	1	(50305)	Inlet Filter
53	1	(37100)	Overload Heater Relay
54	1	(53403)	Valve, Relief

*Not shown on Figures

TABLE A-3
PARTS LIST FOR EXPANDER MODULE, TWO-STAGE DE-202
Reference Figure A-3 (a) and (b)

Item	Qty.	APCI Part No.	Description
1	1	201115C	Valve Motor Assembly
2	1	201624C-G501	Valve Assembly
3	1	250487B	Valve Stem Assembly
4	1	250488C	1st & 2nd Stage Displacer Assembly
5	1	201211C-G506	Cylinder Assembly
6	1	201087C	Housing, Motor
7	1	201620C	Motor Base Assembly
8	1	201110C	Motor Valve
9	2	77647A	Compression Spring
10	2	201115C-9	Roll Pin
11	1	(35900)	Receptacle
12	1	201115C-11	O-Ring
13	1	201115C-12	O-Ring
14	2	201115C-13	Capscrew
15	4	201115C-14	Capscrew
16	4	201115C-15	Lock washer
17	2	201115C-16	Stat-O-Seal
18	2	96297B	Adapter Fitting
19	2	(44701)	Coupling Half
20	2	(47101)	O-Ring
21	8	201115C-20	Capscrew
22	8	201115C-21	Flat washer
23	8	201115C-22	Lock washer
24	1	201115C-23	O-Ring
25	1	201115C-24	O-Ring
26	2	(45301)	Dust Cap
27	2	250487B-6	O-Ring
28	4	96760C	Ring Piston Crescent
29	2	250488C-9	O-Ring
30	2	201189C	Ring Piston Crescent
31	1	250488C-11	O-Ring
32	1	250488C-13	Spring, Garter
33	2	200233C	Ring Piston Crescent

TABLE A-4
PARTS LIST FOR ELECTRICAL BOX ASSEMBLY
AIR-& WATER-COOLED
Reference Figure A-4

Item	Qty.	APCI Part No.	Description
1	1	251095D	Electrical Box, Water-& Air-Cooled Compressor
2	2	201297A	Support, Electrical Box
3	1	96616B	Clamp Capacitor
4	1	(32500)	Capacitor Run
5	1	(32900)	Capacitor Start
6	1	(37400)	Relay
7	1	(32700)	Capacitor
8	1	(32904)	Resistor
9	1	(39000)	Toggle Switch
10	1	(34800)	Light Neon
11	2	250392D-12	Fuse Holder
12	2	(32000)	Terminal Block
13	1	250392D-16	Resistor
14	31	250392D-17	Terminal
15	50 ft	250392D-19	Wire No. 16
16	1	(39400)	Auto Transformer
17	3	250392D-22	Connector 90° Angle Squeeze Type
18	1	250392D-35	Clamp Capacitor
19	1	250392D-37	Resistor
20	REF	250388D	Wiring Diagram (with Transformer)
21	REF	250390D	Wiring Diagram (without Transformer)
22	4	2500392-44	Jumper Plate
23	1	2500392-45	Jumper Plate
24	1	(35002)	Elapsed Time Meter
25	1	201482C	Cover Electrical Box (Not Shown)

TABLE A-5
PARTS LIST FOR DISPLEX CRYOPANEL ARRAY
(Reference Figure A-5)

Item	Qty.	APCI Part No.	Description
1	1	251475C-G506	Cryopanel, 1st stage Ass'y (Nom 6")
2	1	251474C-G506	Cold panel, 2nd stage Ass'y (Nom 6")
3	1	251514C	Chevron Assembly 6 inch
4	1	251475C-G508	Cryopanel 1st Stage Assy (Nom 8")
5	1	251474C-G508	Cold panel 2nd Stage Assy (Nom 8")
6	1	251515C	Chevron Assembly 8-inch
7	1	—	Cryopump Gasket Set
8	4	—	Capscrew St St'l 5-40NC X
9	4	—	Washer Flat St St'l No. 5
10	4	—	Washer Lock St St'l No. 5
11	1	—	Capscrew St St'l ¼-28NF x ¼ Lg
12	1	—	Washer Flat St'l ¼
13	4	—	Hex Nut St St'l *4-40 UNC
14*	1	SK8284C	Cryopanel, 2nd Stage (Nom 6") For H_2 High Capacity

*Not Shown.

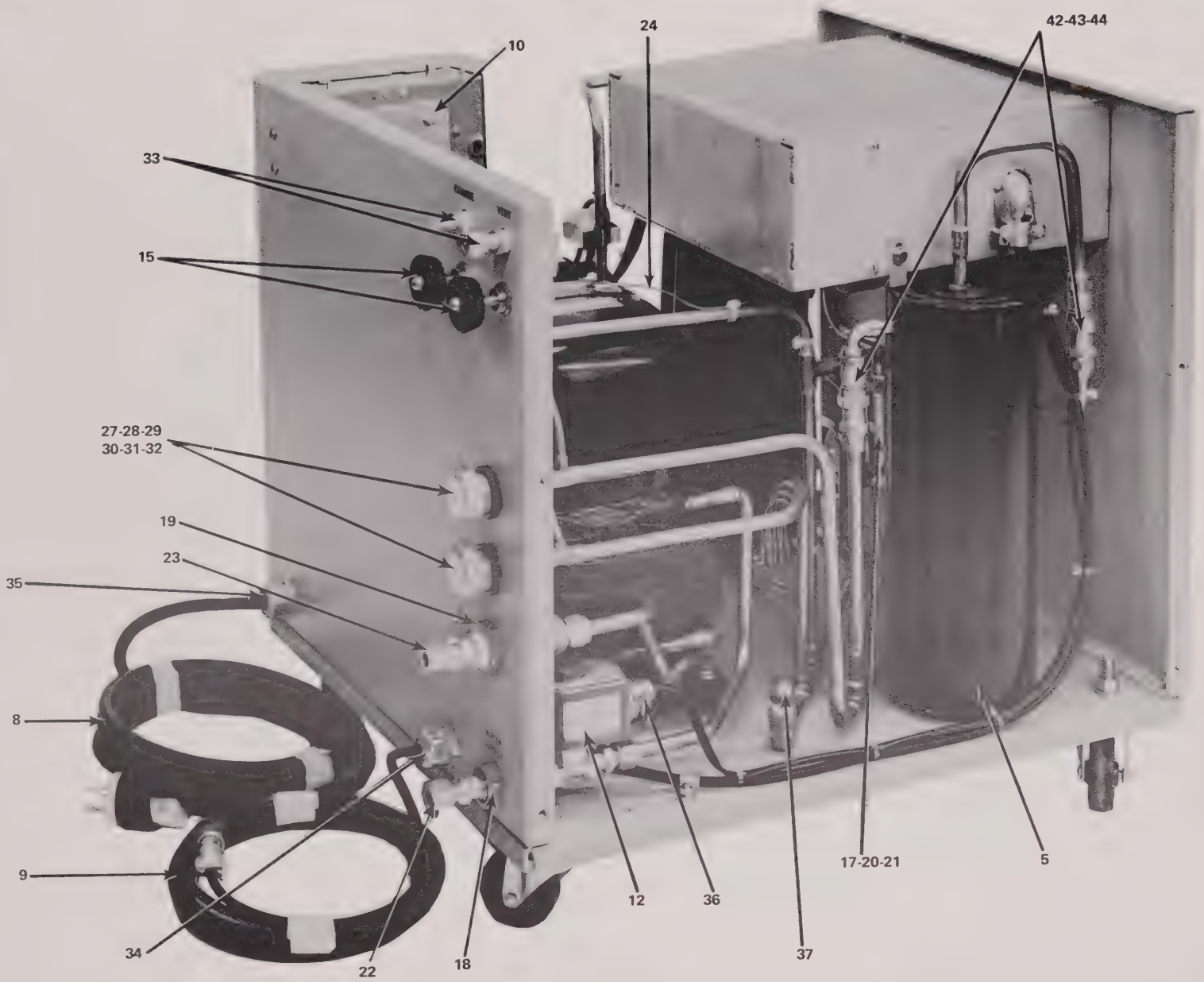


Figure A-1 (a) Water Cooled Compressor Parts Identification

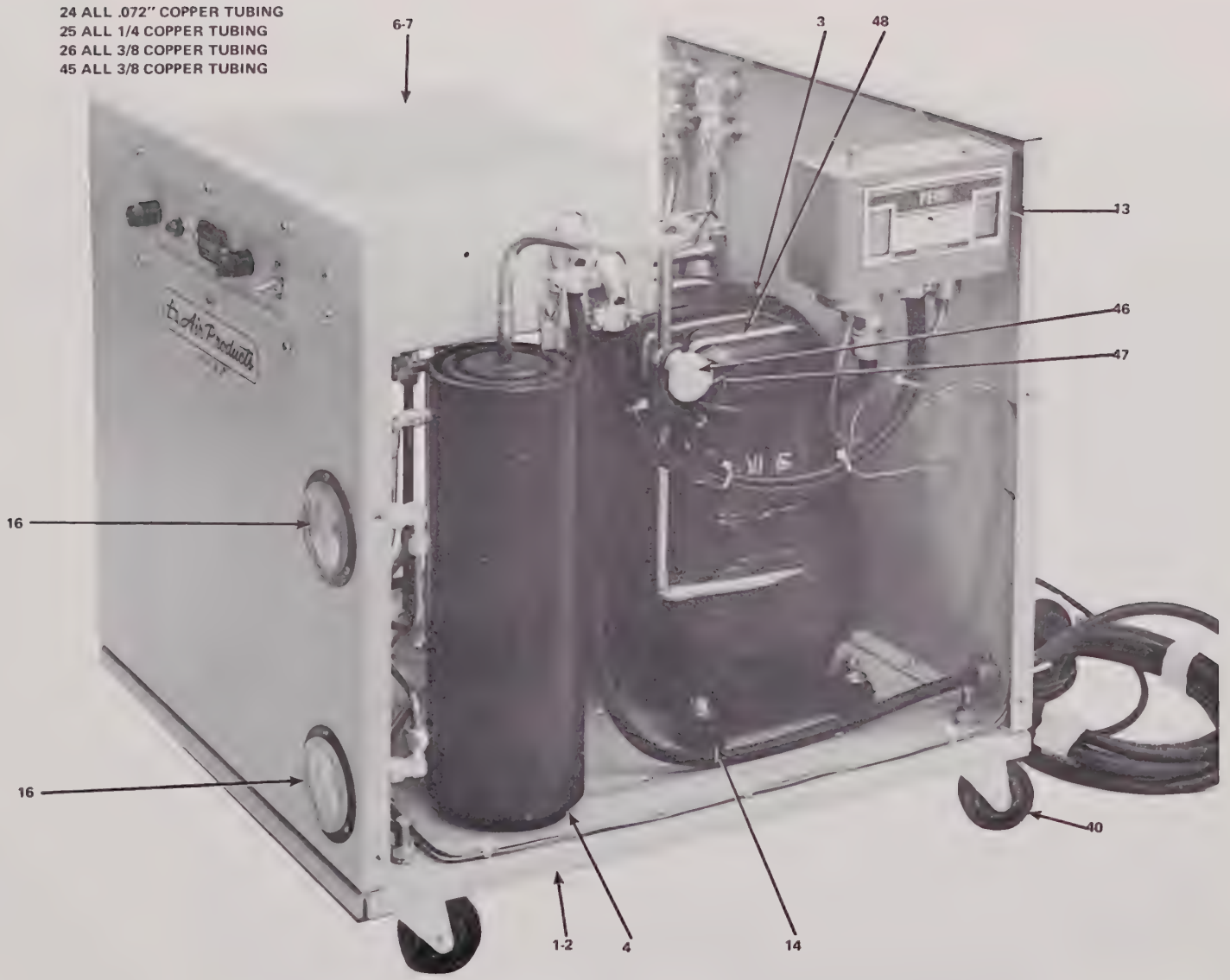


Figure A-1 (b) Water Cooled Compressor Parts Identification

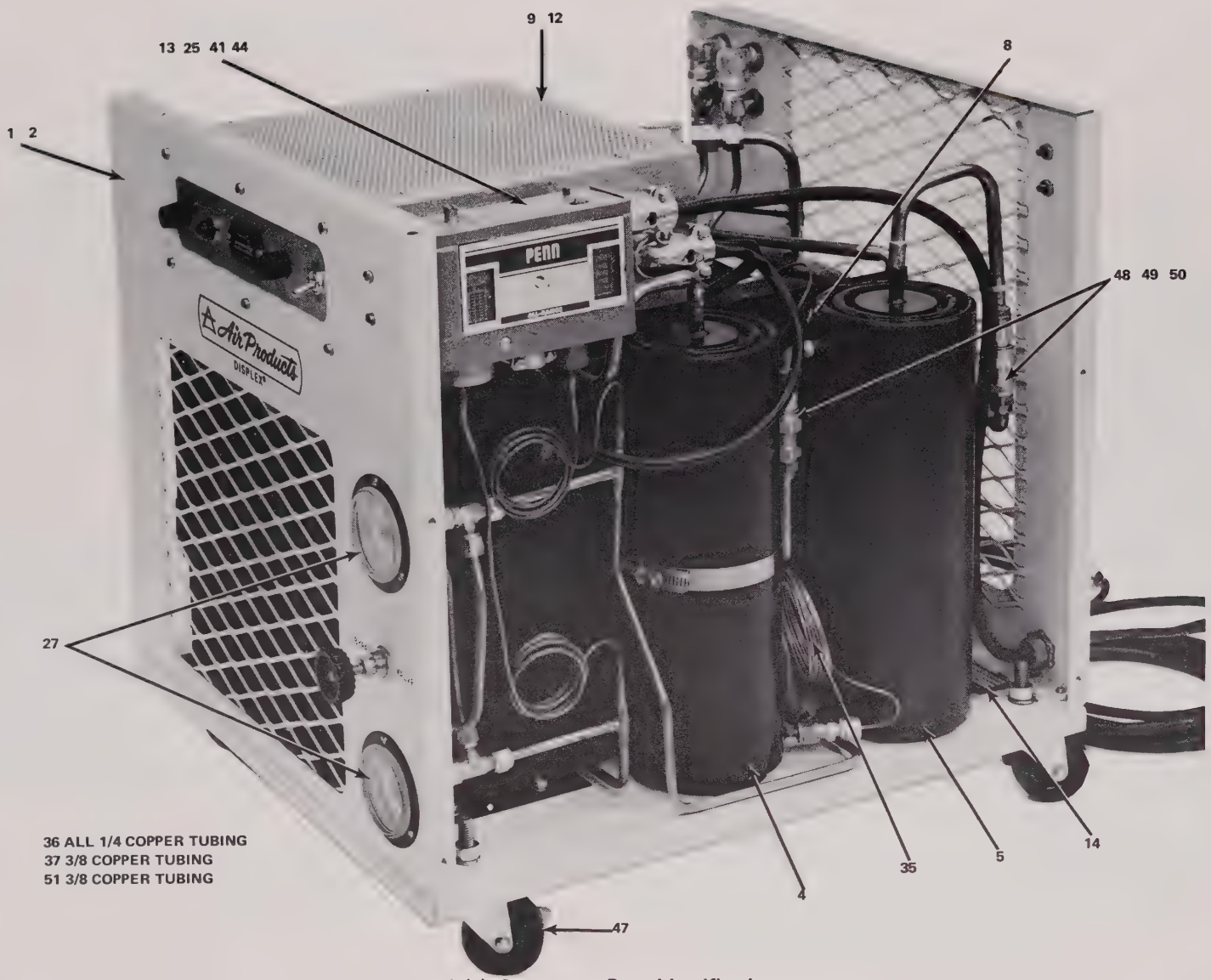


Figure A-2 (a) Compressor Parts Identification

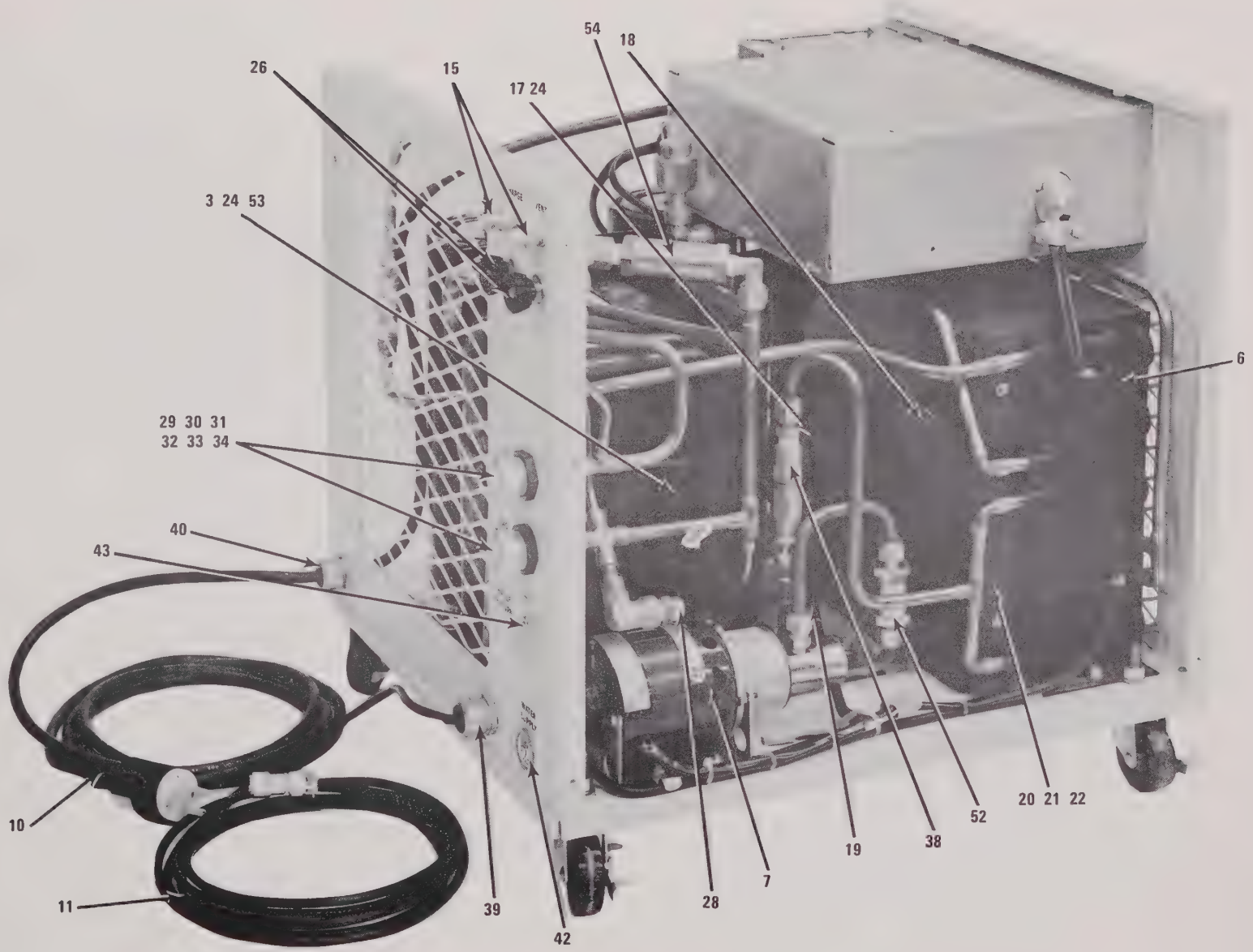


Figure A-2 (b) Compressor Parts Identification

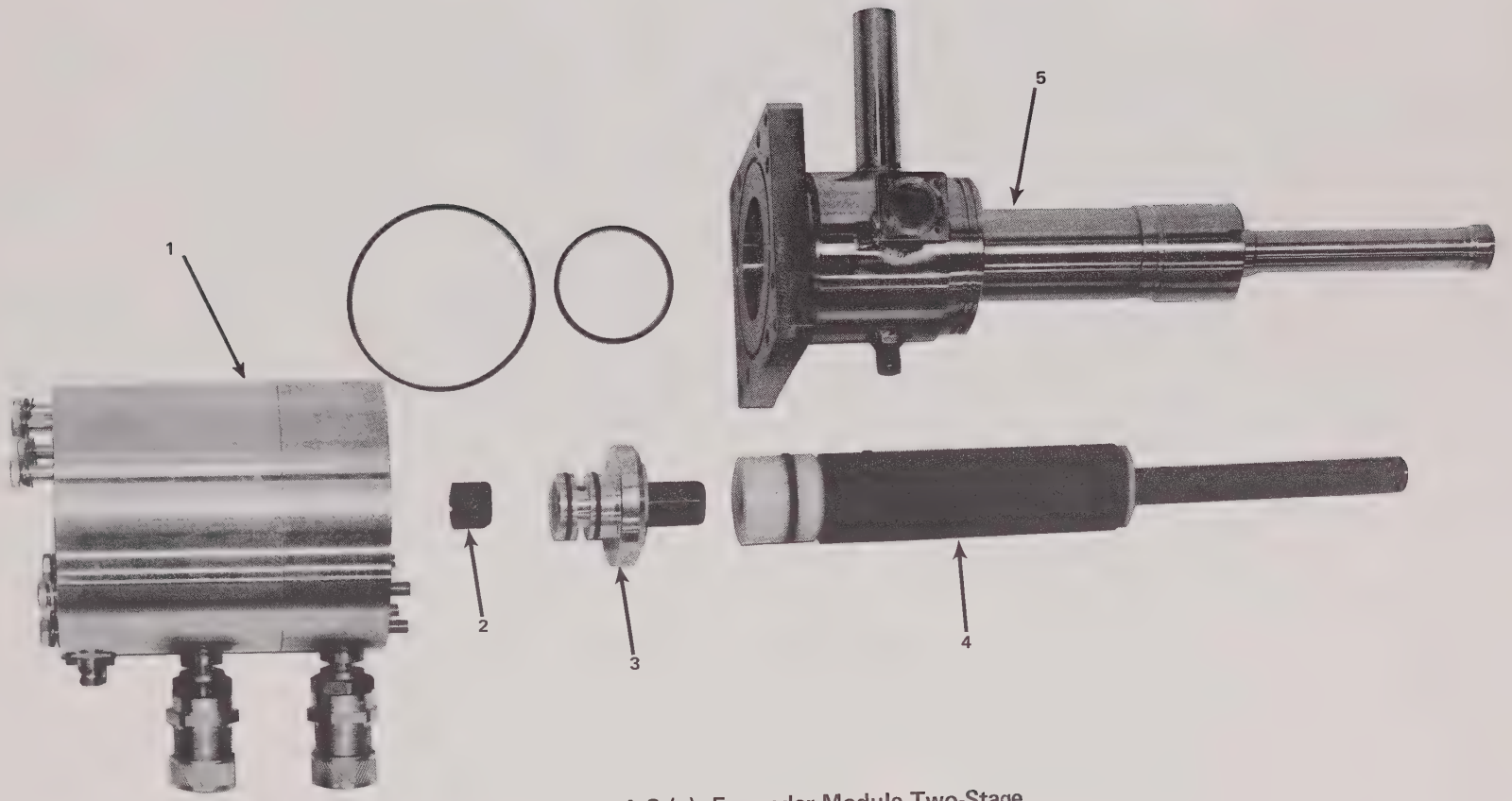


Figure A-3 (a) Expander Module Two-Stage
DE-202 (Sub Assembly View)

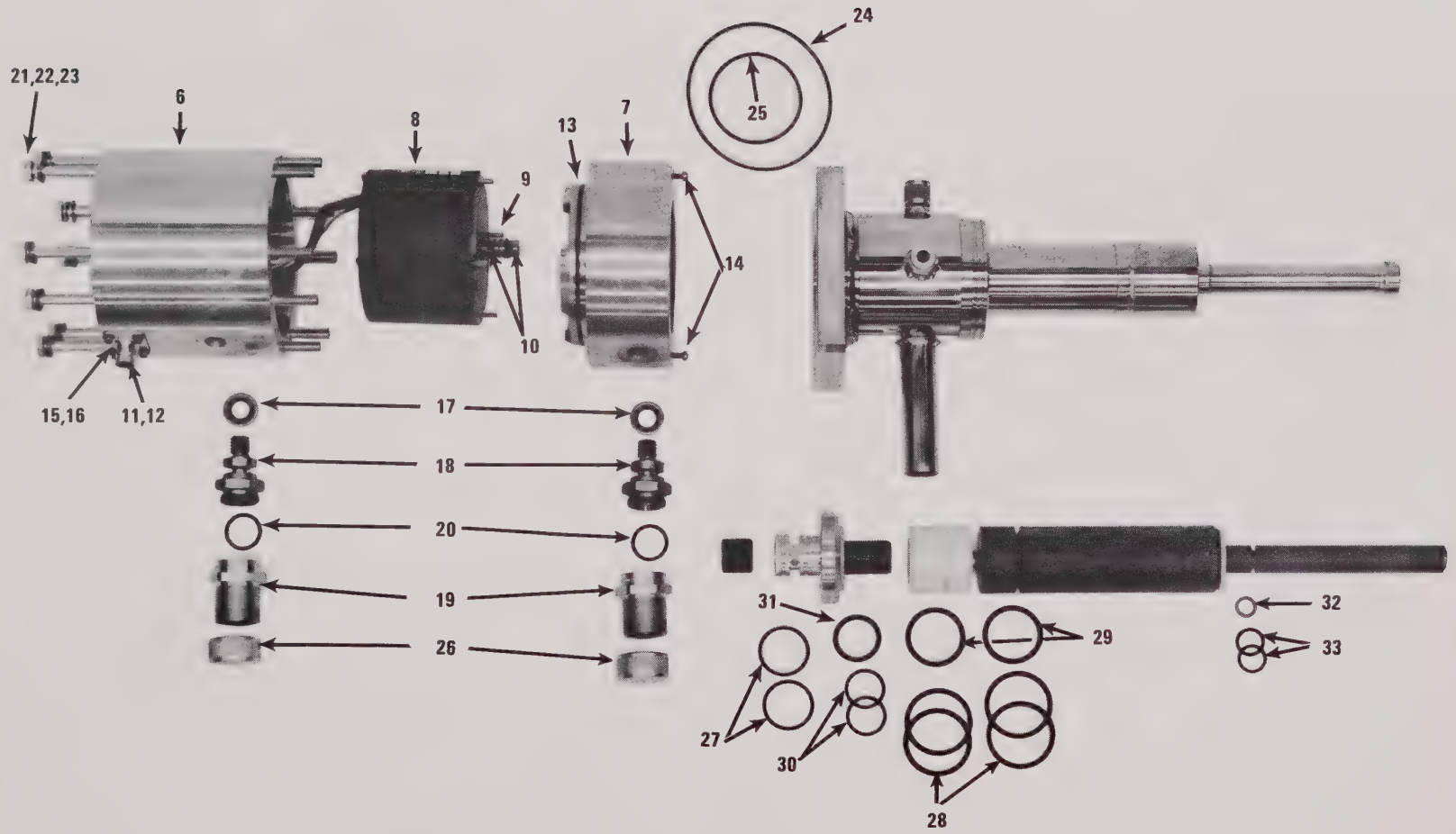


Figure A-3 (b) Expander Module Two Stage DE-202 (Exploded View)

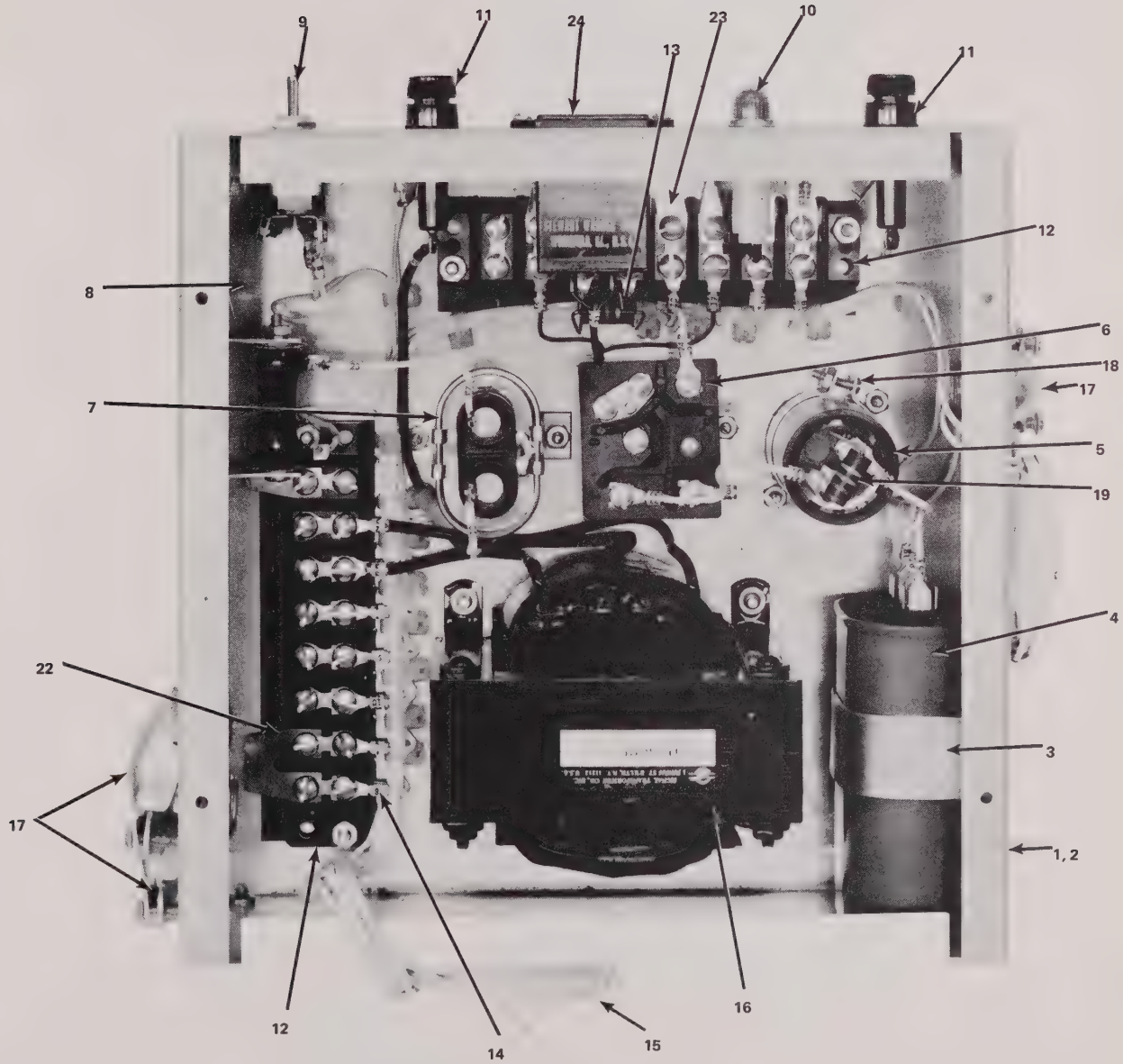


Figure A-4 Electrical Box Ass'y.

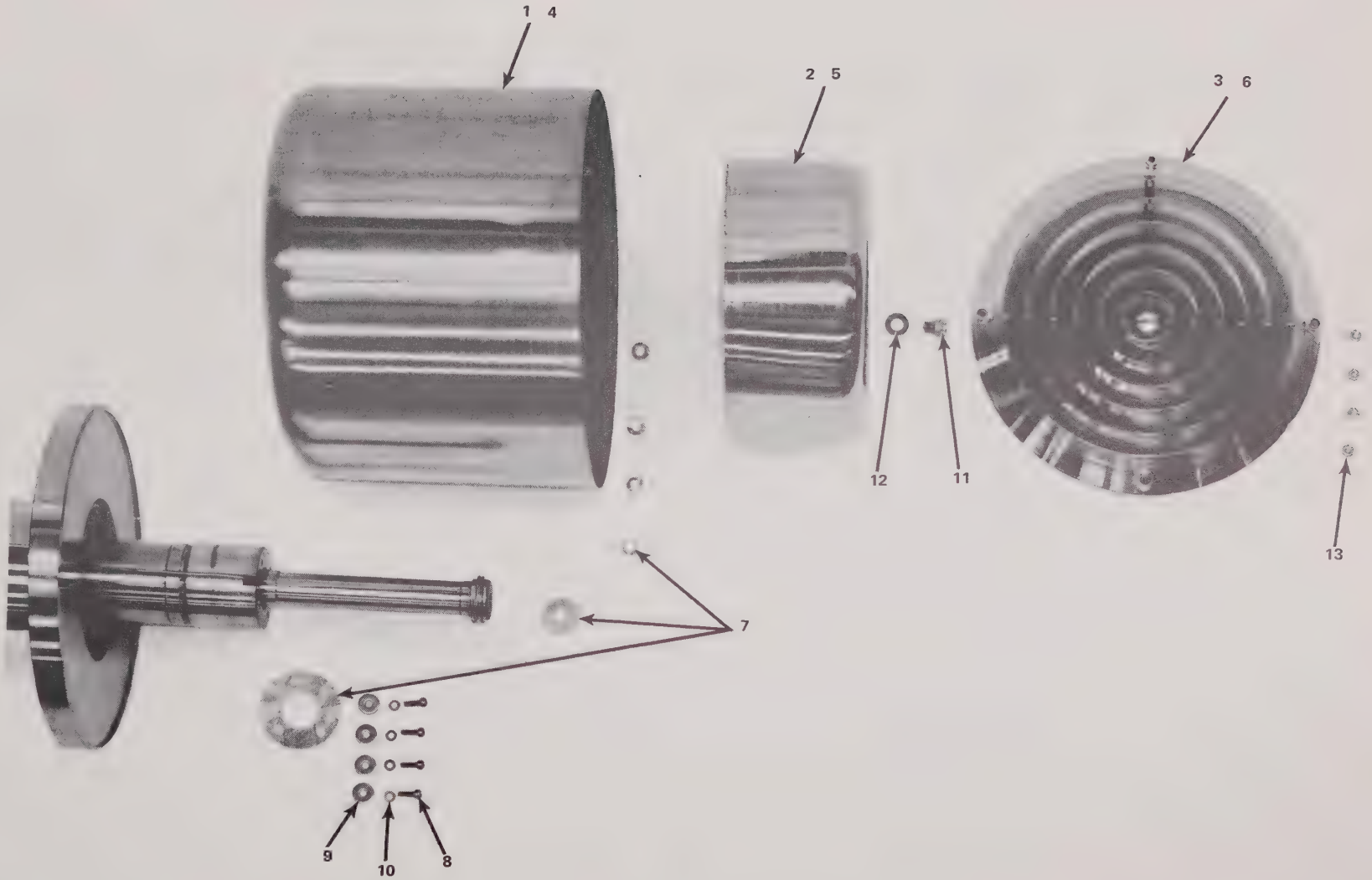


Figure A-5 Displex Cryopanel Array Spare Parts

APPENDIX B: MAINTENANCE KIT ITEMS

TABLE B-1
MAINTENANCE KIT FOR DISPLEX
MODELS CSW-202, CSA-202, AND HV-202

Expander Module (Part number) 251602A After Every 9000 Operating Hours.

Kit Includes:

Item	Qty.	APCI Part No.	Description
1	4	96760C	Ring, Piston Crescent
2	2	201189C	Ring, Piston Crescent
3	2	200233C	Ring, Piston Crescent
4	2	250488C-9	O-Ring, Buna-N, 60 Duro Comp N525-6
5	1	250488C-11	O-Ring, Buna-N, 60 Duro Comp N525-6
6	1	201115C-24	O-Ring, Buna-N, 70 Duro Comp N219-7
7	1	201115C-23	O-Ring, Buna-N, 70 Duro Comp N219-7
8	2	250487B-6	O-Ring, Buna-N, 70 Duro Comp N219-7

Compressor Module After Every 9000 Operating Hours.

1		202530C	Adsorber Assembly (for Air and Water Cooled)

TABLE B-2
DISPLEX SPECIAL TOOL KIT
APCI PART NO. 251374A

Kit Includes

Item	Qty.	APCI Part No.	Description
1	1	SK8196A	Dressing Tool For Crescent Ring (96760C)
2	1	SK8197A	Dressing Tool For Crescent Ring (201189C)
3	1	SK8198A	Dressing Tool For Crescent Ring (200233C)
4	1	SK8199A	Ring Seating Tool 2nd Stage DE-202S
5	1	SK8200A	Ring Seating Tool Slack Cap DE-202S
6	1	SK8201A	Piston Puller DE-202S

APPENDIX C: INSTALLATION KIT ITEMS

TABLE C-1
DISPLEX INSTALLATION KIT
for
CS-102 S/A and CS-202 S/A

KIT CONSISTS OF THE FOLLOWING:

Item	Quantity	Description
1	1 each	12-Compartment Plastic Box, Bradley Box No. 512
2	1 each	Outside Label, SK 4787A
3	1 each	Inside Label, SK 5201A
(FOLLOWING PARTS INCLUDED IN PLASTIC BOX)		
4	1 jar	"Cry-Con" Conductive Grease, APCI No. 78703A
5	1 jar	Vacuum Grease, APCI No. 200741A
6	1 each	Indium Sheet, 99.99% pure .005 thick x 1⅝" x 3½"
7	1 each	Solder, Indium, Indalloy No. 1, 1 oz.
8	1 jar	Flux, Solder, Indalloy No. 2, 1 oz.
9	5 (1 box)	Fuse, 15A-250V Dual Element, Buss No. MDA-15
10	6 each	Nut, brass, ¼ Gyrolok No. 4N
11	6 each	Teflon Plug, SK 3015A
12	6 each	Ferrule, Front, Brass, ¼", Gyrolok No. 4FF
13	6 each	Ferrule, Rear, Brass, ¼", Gyrolok No. 4FR
14	12 each	O-Ring, Compound N219-7, 70 Duro 2.489 I.D. x .070 or Eq. W1, Parker No. 2-37
15	12 each	Gasket Seal, Aeroquip No.22008-8
16	6 each	Gasket Seal, Aeroquip No. 22008-4
17	1 set	Polyurethane Foam
18	6 each	O-Ring, Compound N 219-7, 70 Duro., 1.489 I.D. x .070 W1., Parker No. 2-29 or equal
19	1 each	Wrench, open-end thin pattern, 30° angle single Hd drop forged Alloy Steel, chrome plated 1" nom opening 7 1/16" long (approx) Armstrong Armalloy No. 1232 or equal
21	4 each	O-Ring, Compound N219-7, 70 Duro., .364 I.D. x .070 W1, Parker No. 2-12 or equal
22	8 each	O-Ring, Compound N219-7, 70 Duro., .676 I.D. x .070 W1, Parker No. 2-17 or equal
23	2 each	Adapter Fitting SK5401A-G501
24	2 each	Adapter Fitting SK-8217A

TABLE C-2
DISPLEX INSTALLATION KIT
for CS-102 S/W and CS-202 S/W

KIT CONSISTS OF THE FOLLOWING:

Item	Quantity	Description
1	1 each	12-Compartment Plastic Box, Bradley Box No. 512
2	1 each	Outside Label, SK 4787A
3	1 each	Inside Label, SK-5201A
(FOLLOWING PARTS INCLUDED IN PLASTIC BOX)		
4	1 jar	"Cry-Con" Conductive Grease, APCI No. 78703A
5	1 jar	Vacuum Grease, APCI No. 200741A
6	1 each	Indium Sheet, 99.99% pure .005 thick x 1⅝ x 3½"
7	1 each	Solder, Indium, Indalloy No. 1, 1 oz.
8	1 jar	Flux, Solder, Indalloy No. 2, 1 oz.
9	5 (1 box)	Fuse, 15A-250V Dual Element, Buss No. MDA-15
10	6 each	Nut, brass, ¼ Gyrolok No. 4N
11	6 each	Teflon Plug, SK3015A
12	6 each	Ferrule, Front, Brass, ¼", Gyrolok No. 4FF
13	6 each	Ferrule, Rear, Brass, ¼", Gyrolok No. 4FR
14	12 each	O-Ring, Compound N 219-7, 70 Duro., 2.489 I.D. x .070 W1, Parker No. 2-37 or equal
15	12 each	Gasket Seal, Aeroquip No. 22008-8
16	6 each	Gasket Seal, Aeroquip No. 22008-4
17	1 set	Polyurethane Foam
18	6 each	O-Ring, Compound N219-7, 70 Duro. 1.489 I.D. x .070 W1 Parker 2-29 or equal
19	1 each	Wrench, open-end thin pattern, 30° angle single HD drop forged Alloy Steel, chrome plated 1" nom opening 7 1/16" long (approx) Armstrong Armalloy No. 1232 or equal
20	1 each	Wrench, open-end thin pattern, 30° angle single HD drop forged Alloy Steel, chrome plated 1-3/16" nom opening 7 1/16" long (approx) Armstrong Armalloy No. 1238 or equal
21	4 each	O-Ring, Compound N219-7, 70 Duro. .364 I.D. x .070 W1 Parker 2-12 or equal
22	8 each	O-Ring, Compound N219-7, 70 Duro. .676 I.D. x .070 W1 Parker 2-17 or equal
23	40 ft.	Tubing, Polyethylene, Natural Color, ⅜" OD Imperial Eastman Poly-Flo No. 66-P-⅜
24	2 each	Adapter Fitting SK 5401A-G501
25	2 each	Ferrule, front, brass, ⅜ tube OD Gyrolok 6FF
26	2 each	Ferrule, rear, brass, ⅜ tube OD Gyrolok 6FR
27	2 each	Adapter Fitting SK-8217A

TABLE C-3
INSTALLATION KIT FOR DISPLEX CRYOPUMPS WITH AIR-COOLED COMPRESSOR

KIT CONSISTS OF THE FOLLOWING:

Item	Quantity	Description
1	1 each	Indium Sheet, 99.99% pure .005 thick x 1⅝'' x 3½''
2	2 each	Fuse, 15A-250V Dual Element, Buss No. MDA-15
3	12 each	Gasket Seal, Aeroquip No.22008-8
4	6 each	Gasket Seal, Aeroquip No. 22008-4
5	1 each	Wrench, open-end thin pattern, 30° angle single Hd drop forged Alloy Steel, chrome plated 1'' nom opening 7 1/16'' long (approx) Armstrong Armalloy No. 1232 or equal
6	1 each	Wrench, open-end thin pattern, 30° angle single Hd drop forged Alloy Steel, chrome plated 1-3/16'' nom opening 7 1/16'' long (approx) Armstrong Armalloy No. 1232 or equal
7	2 each	Adapter Fitting SK 5401A-G501
8	2 each	Adapter Fitting SK-8217A

TABLE C-4
INSTALLATION KIT FOR DISPLEX CRYOPUMPS WITH HIGH BACK PRESSURE WATER-COOLED COMPRESSORS

KIT CONSISTS OF THE FOLLOWING:

Item	Quantity	Description
1	1 each	Indium Sheet, 99.99% pure .005 thick x 1⅝ x 3½"
2	2 each	Fuse; 15A-250V Dual Element, Buss No. MDA-15
3	12 each	Gasket Seal, Aeroquip No. 22008-8
4	6 each	Gasket Seal, Aeroquip No. 22008-4
5	1 each	Wrench, open-end thin pattern, 30° angle single Hd drop forged Alloy Steel, Chrome plated 1" nom opening 7 1/16" long (approx) Armstrong Armalloy No. 1232 or equal
6	1 each	Wrench, open-end thin pattern, 30° angle single Hd drop forged Alloy Steel, Chrome plated 1 3/16" nom opening 7 1/16" long (approx) Armstrong Armalloy No. 1238 or equal
7	40 ft.	Tubing, Polyethylene, natural color, ⅜" OD, Imperial Eastman Poly-Flo No. 66-P-⅜
8	2 each	Adapter Fitting SK 5401A-G501
9	2 each	Adapter Fitting SK 8217A
10	2 each	Nut, brass, ⅜ tube OD Gyrolok 6N
11	2 each	Ferrule front brass ⅜ tube OD Gyrolok 6FF
12	2 each	Ferrule rear, brass ⅜ tube OD Gyrolok 6FR

APPENDIX D: INSTRUMENTATION DATA

D.1 THERMOCOUPLE READOUT.

If the system is equipped with a thermocouple for temperature measurements, the dissimilar metals involved will be chromel versus gold with 0.07 atomic % iron. Data on this thermocouple has been obtained by the NBS and reported in reference [1]. This thermocouple is very stable with time and temperature cycling. It has been found, however, that there is considerable deviation in the thermal voltage-temperature relation from one batch of thermocouple wire to the next. Most of this variation is in the region below 25°K with a maximum difference at 4.2°K of about 2°K.

It has been our experience that the errors introduced by slight differences in mounting, temperature gradients in regions where the wire has been strained, improper heat stationing, etc., are small when care is taken in mounting the thermocouple wire. Most of the "error" in temperature readout is thus associated with differences between the actual thermal voltage of the material and the published data. The thermocouple can thus be calibrated and can be expected to give reproducible readings plus or minus .1°K with repeated use.

The use of the thermal voltage Table D-1 is illustrated by use of the following example:

Assume that an individual is using an ice bath (273°K) reference junction and that he is measuring the voltage output from the chromel versus gold 0.07% iron; the voltage is -4.980 mv. What is his refrigerator cold end temperature?

From Table D-1

For ice reference (273°K), thermal voltage is:	5.309 mv
Thermocouple output	-4.980 mv
Algebraic sum	+0.329 mv

Looking at Table D-1, for thermal voltage of +0.329 mv the corresponding temperature is 22°K.

One method of thermocouple hookup is shown in Figure D-1. Solder a short length of the gold thermocouple wire to the end of the chromel wire. Immerse this junction in a tube partly filled with kerosene, oil, or other non-conducting liquid and place the tube in an ice water bath. Connect the two gold leads to the potentiometer. The connection to the chromel leg is the positive connection.

CAUTION

DO NOT USE ANY SOLDER CONTAINING LEAD TO SOLDER TO THE GOLD THERMOCOUPLE WIRE, AS LEAD AMALGAMATES WITH THE GOLD. USE A LEAD-FREE SOLDER SUCH AS INDALLOY NO. 1.

D.2 VAPOR BULB READOUT.

Figure D-2 gives the vapor pressure of hydrogen as a function of temperature. Direct reading of this curve gives temperature when pressure is read from the vapor bulb pressure gauge.

[1] "LOW-TEMPERATURE THERMOCOUPLES:" KP, "Normal" Silver, and copper versus Au-0.02 at % Fe and Au-0.07 at % Fe, L. L. Sparks and R. L. Powell, J. Res N.B.S., Vol. 76A, No. 3, May-June, 1972, pp. 263-283.

TABLE D-1

Thermocouple KP versus Au-0.07 Atomic % Fe_{11} — Temperature vs Thermoelectric Voltage

T °K	E μV	T °K	E μV	T °K	E μV	T °K	E μV	T °K	E μV
0	0.00	60	962.74	120	2065.91	180	3285.35	240	4576.81
1	7.85	61	979.90	121	2085.44	181	3306.38	241	4598.74
2	17.27	62	997.11	122	2105.00	182	3327.43	242	4620.69
3	28.04	63	1014.36	123	2124.59	183	3348.50	243	4642.64
4	39.96	64	1031.65	124	2144.21	184	3369.58	244	4664.61
5	52.86	65	1048.99	125	2163.87	185	3390.69	245	4686.58
6	66.59	66	1066.36	126	2183.55	186	3411.81	246	4708.56
7	81.03	67	1083.79	127	2203.26	187	3432.96	247	4730.55
8	96.04	68	1101.25	128	2223.00	188	3454.12	248	4752.55
9	111.52	69	1118.76	129	2242.78	189	3475.30	249	4774.56
10	127.40	70	1136.32	130	2262.58	190	3496.49	250	4796.58
11	143.59	71	1153.92	131	2282.41	191	3517.71	251	4818.61
12	160.03	72	1171.56	132	2302.27	192	3538.94	252	4840.64
13	176.65	73	1189.24	133	2322.16	193	3560.20	253	4862.69
14	193.42	74	1206.96	134	2342.07	194	3581.47	254	4884.75
15	210.29	75	1224.73	135	2362.02	195	3602.75	255	4906.82
16	227.23	76	1242.55	136	2381.99	196	3624.06	256	4928.90
17	244.21	77	1260.40	137	2401.99	197	3645.38	257	4950.99
18	261.20	78	1278.30	138	2422.01	198	3666.72	258	4973.09
19	278.19	79	1296.24	139	2442.07	199	3688.08	259	4995.20
20	295.17	80	1314.22	140	2462.15	200	3709.45	260	5017.33
21	312.12	81	1332.24	141	2482.25	201	3730.84	261	5039.46
22	329.04	82	1350.30	142	2502.39	202	3752.25	262	5061.61
23	345.92	83	1368.41	143	2522.55	203	3773.68	263	5083.77
24	362.75	84	1386.56	144	2542.73	204	3795.12	264	5105.94
25	379.54	85	1404.75	145	2562.94	205	3816.58	265	5128.12
26	396.28	86	1422.98	146	2583.18	206	3838.05	266	5150.31
27	412.98	87	1441.25	147	2603.45	207	3859.54	267	5172.52
28	429.64	88	1459.57	148	2623.73	208	3881.05	268	5194.73
29	446.26	89	1477.92	149	2644.05	209	3902.58	269	5216.96
30	462.84	90	1496.32	150	2664.39	210	3924.12	270	5239.19
31	479.39	91	1514.75	151	2684.75	211	3945.67	271	5261.44
32	495.92	92	1533.23	152	2705.14	212	3967.24	272	5283.70
33	512.42	93	1551.74	153	2725.55	213	3988.83	273	5305.96
34	528.90	94	1570.30	154	2745.99	214	4010.43	274	5328.23
35	545.37	95	1588.89	155	2766.45	215	4032.05	275	5350.51
36	561.83	96	1607.53	156	2786.94	216	4053.69	276	5372.79
37	578.28	97	1626.20	157	2807.45	217	4075.33	277	5395.08
38	594.73	98	1644.92	158	2827.98	218	4097.00	278	5417.36
39	611.19	99	1663.67	159	2848.54	219	4118.67	279	5439.65
40	627.66	100	1682.46	160	2869.12	220	4140.36	280	5461.94
41	644.13	101	1701.29	161	2889.72	221	4162.07		
42	660.63	102	1720.16	162	2910.35	222	4183.79		
43	677.14	103	1739.06	163	2931.00	223	4205.52		
44	693.67	104	1758.00	164	2951.67	224	4227.27		
45	710.22	105	1776.98	165	2972.37	225	4249.03		
46	726.81	106	1796.00	166	2993.08	226	4270.80		
47	743.42	107	1815.05	167	3013.82	227	4292.58		
48	760.06	108	1834.14	168	3034.58	228	4314.38		
49	776.74	109	1853.27	169	3055.37	229	4336.19		
50	793.45	110	1872.43	170	3076.17	230	4358.01		
51	810.20	111	1891.62	171	3096.99	231	4379.84		
52	826.99	112	1910.85	172	3117.84	232	4401.68		
53	843.81	113	1930.12	173	3138.71	233	4423.54		
54	860.68	114	1949.42	174	3159.60	234	4445.40		
55	877.58	115	1968.75	175	3180.51	235	4467.28		
56	894.53	116	1988.12	176	3201.44	236	4489.17		
57	911.52	117	2007.52	177	3222.38	237	4511.06		
58	928.55	118	2026.95	178	3243.35	238	4532.97		
59	945.63	119	2046.41	179	3264.34	239	4554.88		
60	962.74	120	2065.91	180	3285.35	240	4576.81		

WARNING

READ THIS ENTIRE MANUAL BEFORE ATTEMPTING ANY ADJUSTMENTS. READJUSTMENT OR ALIGNMENT (IF ANY ARE NECESSARY) ARE USUALLY MINOR, BUT DO REQUIRE SOME TEST EQUIPMENT. PERSONNEL MAKING THESE ADJUSTMENTS SHOULD HAVE A BASIC UNDERSTANDING OF ELECTRONIC MAINTENANCE AND R.F. IF ANY DOUBT EXISTS, PLEASE CALL PERKIN-ELMER ULTEK INC. BEFORE PROCEEDING.

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SECTION 1
SPECIFICATIONS, GENERAL INFORMATION

SPECIFICATIONS

Operating frequency	13.56 MHz
Frequency stability	±2 KHz
Input impedance	52 ohm
Output impedance	52 ohm with SWR not to exceed 3:1 (reflected power not to exceed 25%).
Exciter	Crystal-controlled, 6780 KHz oscillator with internal buffer/doubler.

Complete overload protection, remote operation, mounted on casters.

Harmonic and other spurious radiation reduced in accordance with FCC regulations and OSHA standards.

1000 W Generator	
Exciter	0 through 150 W output
Generator	0 through 1000 W output continuous-duty.
Shipping weight	264 lbs (120 kg)
Dimensions	44"H x 24"D x 24"W (112 cm x 61 cm x 61 cm)
2000 W Generator	
Exciter	0 through 300 W output
Generator	0 through 2000 W output continuous-duty.
Shipping weight	326 lbs (148 kg)
Dimensions	44"H x 24"D x 24"W (112 cm x 61 cm x 61 cm)
3000 W Generator	
Exciter	0 through 400 W output
Generator	0 through 3000 W output continuous-duty.
Shipping weight	529 lbs (240 kg)
Dimensions	53"H x 24"D x 24"W (135 cm x 61 cm x 61 cm)

INTRODUCTION

Make certain the generator is operated on the line voltage specified on the red tag secured to the front door. Refer to Section 3 for line voltage changeover.

Information in this manual is pertinent to all 1000, 2000, and 3000 W generators unless otherwise specified.

The R.F. power generators consist of a crystal-controlled exciter section, a one-stage linear power amplifier, and a power supply capable of delivering all necessary operating voltages. The generator delivers its rated output for continuous-duty operation.

UNPACKING

Remove the generator from its shipping box and packing material and examine it carefully for visible damage. If the generator has been damaged in shipment, save the shipping container and packing material and notify the transport company immediately. The equipment warranty is invalidated by damage caused in transit.

OPERATING LOCATIONS AND POWER CONNECTIONS

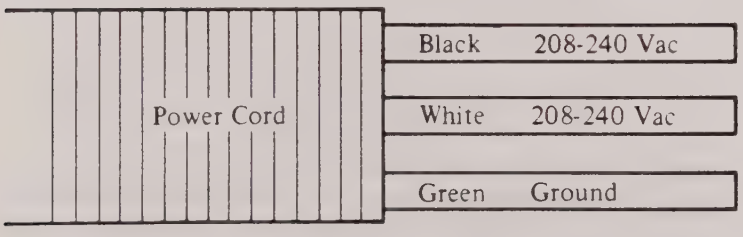
The power tube develops high temperatures during operation, so the generator should be situated where it can be properly cooled. The equipment should be placed far enough away from any wall, furniture, or surface to allow an adequate flow of cool air through the rear vent. *Avoid placing any objects on the ventilating grill on top of the generator.*

Locate the generator near an adequate source of power. Connect the power cord to the power source as follows: black wire – 208-240 Vac, white wire – 208-240 Vac, green wire – ground. See Figure 1.

Please note that this generator is a two-wire device. The green wire in the power cord provides an equipment ground only. *Do not apply any voltage or current carrying neutral to this wire!*

WARNING

DO NOT TILT THE GENERATOR WHILE IT IS ON. THE HIGH VOLTAGE RELAYS MAY BE ACCIDENTALLY ACTIVATED.



Current requirements.
1000 W : 25A
2000 W : 40A
3000 W : 50A

Figure 1. Power Cord Connections.

WARNING

THE OPERATING VOLTAGES INSIDE THE GENERATOR ARE LETHAL. ALWAYS USE THE UTMOST CAUTION WHEN WORKING INSIDE THE GENERATOR.

CONTROL CABLE CONNECTIONS

Rear output apron connections are as follows:

1. 14-pin MS SK101, control cable to sputter head.
2. 2-pin MS SK102. The generator is shipped from the factory with a shorted plug in this connector. It is used for a customer supplied water flow switch. When this circuit is open, the high voltage circuits are prevented from turning on. No RF power can be generated in this condition.
3. BNC connection* RG 58 cable connected from this plug to programmer stabilizer.
4. 10-pin Jones connector, SK103. Used for connection of alignment and calibration test fixture. Not required for normal operation. (See Section 4).
5. 8A 3AG fuse* installed here to protect 115 V auxiliary circuits in sputter head.
6. RF cable is connected through a grommet on rear to Bird sensor. Access to this cable is obtained by removing rear door.

* not required or installed on all generators.

SECTION 3
OPERATION

OPERATING CAUTIONS

The operating voltages inside the generator are lethal. Do not operate the generator with any of its doors or panels removed unless you observe the *utmost caution!*

Never operate the generator without connecting the RF output to the sputter head or a dummy load. All covers and doors must be securely in place for safe operation. Do not defeat interlocks – they ensure your safety. Always allow about 5 minutes operation with the RF off before turning the generator off. This allows the power tube to cool and prolongs tube life.

OPERATING INSTRUCTIONS

1. Turn on generator circuit breaker (located on front door).
2. Wait 90 seconds for tubes to warm up.
3. Push RF ON button (located on sputter head)*.

1000 W LINE CHANGEOVER

See Figures 2 and 3 for component locations.

When the RF generator is operated at a new location it may be necessary to make the following adjustments for variations in input line voltage. Use a voltmeter to determine the ac line voltage at the operating position and note this voltage.

Adjust the step-down transformer voltage by unsoldering the violet/ white wire and moving it to tap 2, 3, or 4, as determined by the line voltage.

Line voltage = 190-210 Vac, use tap 2

Line voltage = 211-230 Vac, use tap 3

Line voltage = 231-250 Vac, use tap 4

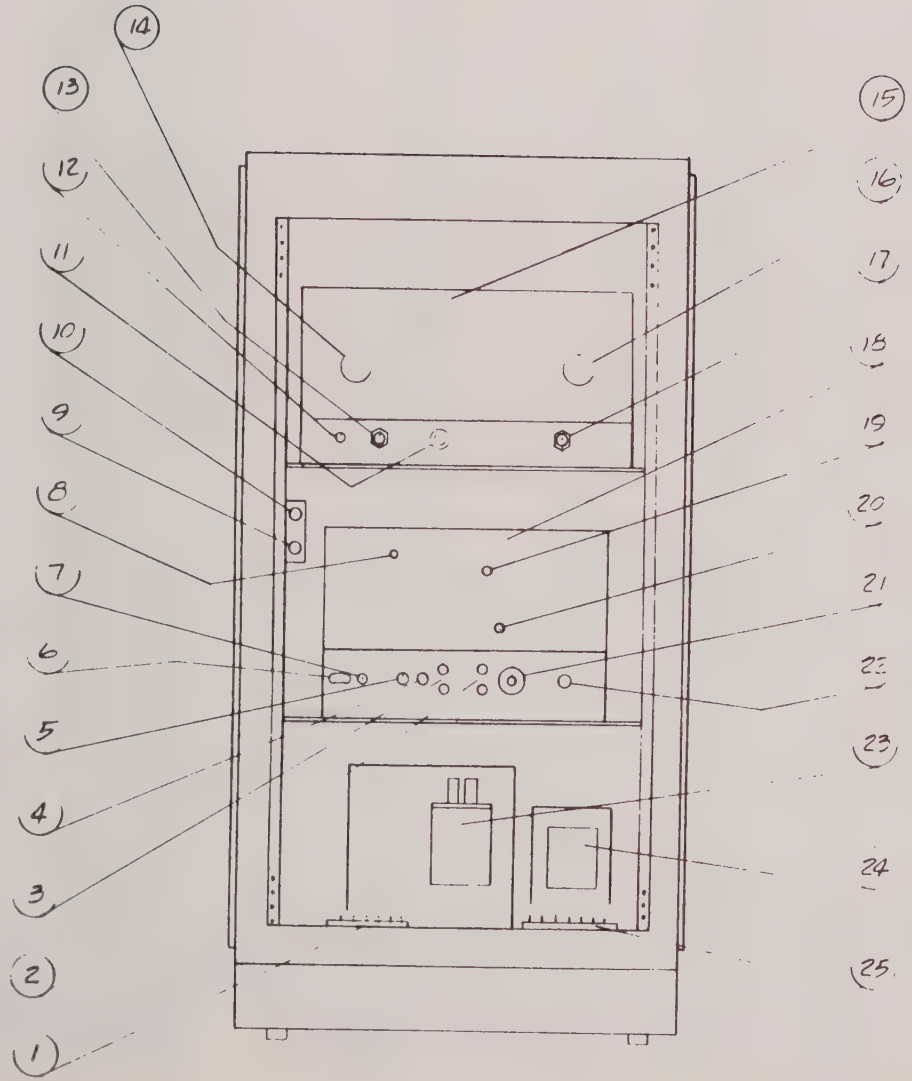
Adjust the plate transformer voltage by moving the large primary wire and the smaller transient suppressor wire between taps 3 and 4, as determined by the line voltage.
Wires to tap 1 are moved, tap 2 is not used.

Line voltage = 190-220 Vac, use tap 3.

Line voltage = 221-250 Vac, use tap 4.

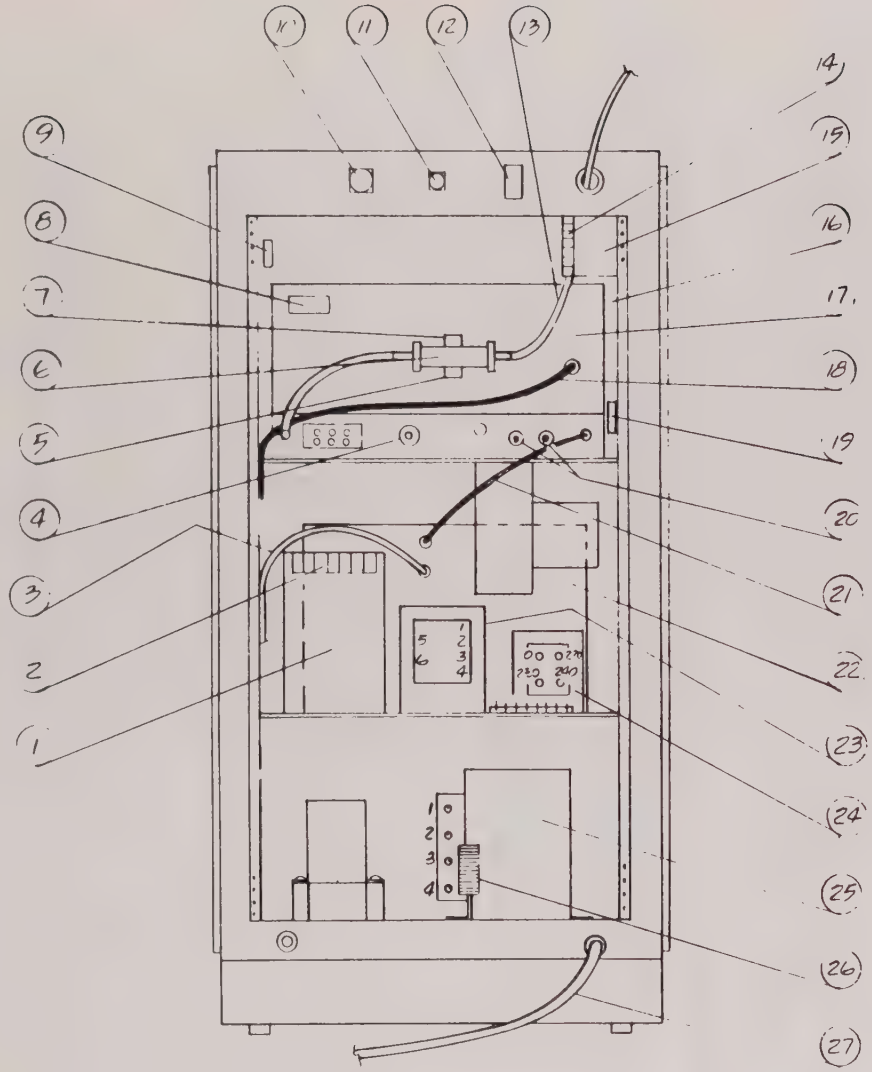
Adjust the filament transformer voltage after connecting a 0-10 Vac voltmeter to the filament connectors (see Table 1) on the rear of the Power Amplifier section. The filament connectors have heavy gauge wires connected to them. Turn on the circuit breaker (on the front door) long enough to observe the filament voltage on the test meter. Turn OFF the circuit breaker. Move the black/ white wire between taps labelled 220-230-240 until the test meter reads 5.5 Vac ±5% when the circuit breaker is turned on. DO NOT MAKE ANY TRANSFORMER TAP CHANGES WITH THE POWER ON.

*3400 models are turned on by a logic signal from the programmer.



25 TB1
24 L1
23 RY1
22 L8 PA Grid Adjustment
21 P2, Exciter Voltage Test Points
20 Power Amplifier Tune Control For Excitor
19 Power Amplifier Load Control For Exciter
18 Exciter
17 Plate Calibration Pot For Test Box
16 Power Amplifier Load Control For Final
15 Power Amplifier Section For Fianl
14 Power Amplifier Tune Control
13 Grid Calibration Pot For Test Box
12 Grid Meter Test Jack With Shorting Plug
11 1½A 3AG Plate Current Protect-Fuse
10 F2 3A 3AG AC Control Fuse
9 F1 3A 3AG AC Control Fuse
8 L5 PA Drive Control
7 L3 Oscillator
6 Crystal 6780 KC
5 1½A 3AG Control Fuse For Exciter
4 1/16A 8AG Screen Fuse For Exciter
3 Cathode Current Test Points For Exciter
2 Grid Current Test Points For Exciter
1 TB601

Figure 2. 1000 Watt Generator, Front View.



1000 WATT RF GENERATOR
REAR VIEW

27 Input Power Cord
26 Transient Suppressor
25 Plate Transformer
24 Filament Transformer for Final
23 Step Down Transformer
22 Exciter
21 R. F. Power Cable from Exciter to Final
20 Filament Power Input to Power Amplifier
19 Rear Door Interlock
18 High Voltage Cable to Power Amplifier
17 Power Amplifier (Final) Deck
16 TB301
15 Flip Flop
14 TB100
13 R.F. Output Cable
12 SK103
11 SK102
10 SK101
9 TB101
8 Model & Serial Number Label
7 Bird 1000 W Element (Forward Power)
6 Bird Sensor
5 Bird 100 Watt Element (Reflected Power)
4 SK201
3 High Voltage Cable to Exciter
2 TB502
1 Control Level Module

Figure 3. 1000 Watt RF Generator, Rear View.

2000 W LINE VOLTAGE CHANGEOVER INSTRUCTIONS

See Figures 4 and 5 for component locations. When the RF generator is installed at a new location it may be necessary to make the following adjustments for variations in input line voltage. Use a voltmeter to determine the ac line voltage at the operating position. Note this voltage.

Adjust the step-down transformer voltage by unsoldering the violet/white wire and moving it to tap 2, 3, or 4 as determined by line voltage.

Line voltage = 190-220 Vac, use tap 2

Line voltage = 211-230 Vac, use tap 3

Line voltage = 231-250 Vac, use tap 4

Adjust the plate transformer voltage by moving the large primary wire and the smaller transient suppressor wire between taps 2 and 3 as determined by line voltage.

Line voltage = 190-220 Vac, use tap 2

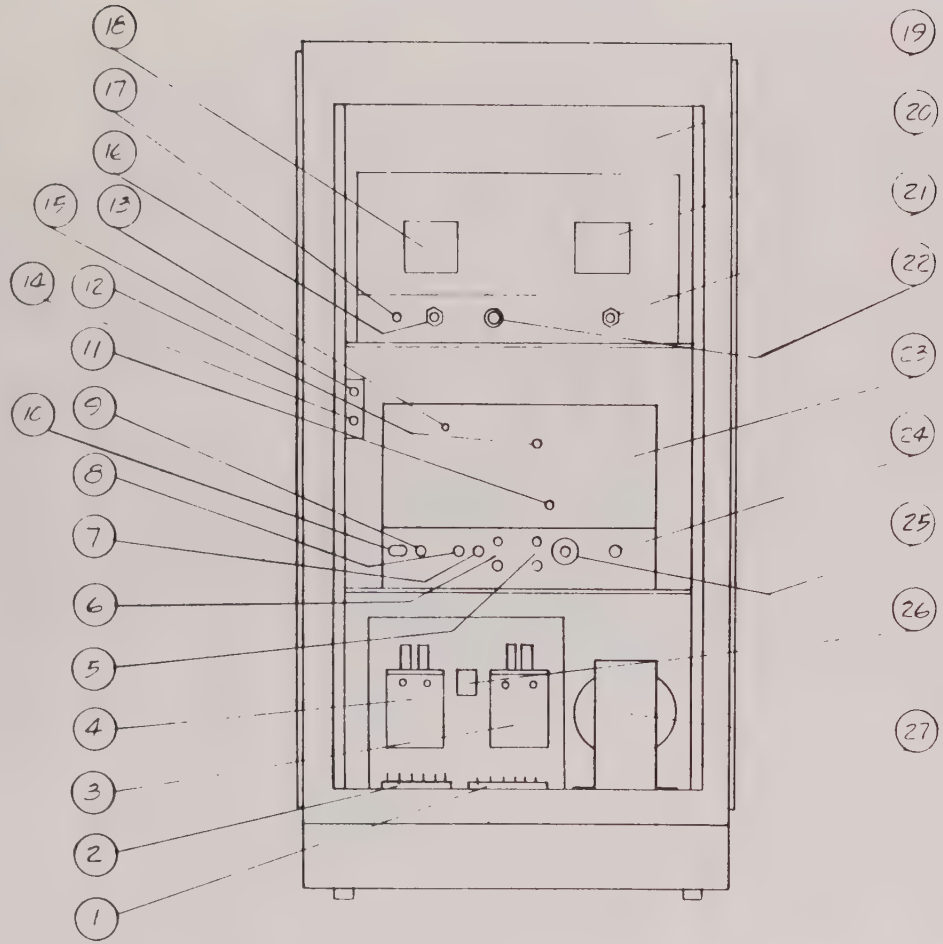
Line voltage = 221-250 Vac, use tap 3

Adjust the filament transformer voltage after connecting a 0-10 Vac voltmeter to the filament connectors on the rear of the power amplifier section. The filament connectors have heavy gauge wires connected to them. Turn on the circuit breaker (on the front door) long enough to observe the filament voltage on the test meter. Turn OFF the circuit breaker. Move the black/white wire between taps 2 through 6 until the test meter reads 8.0 Vac ±5% when the circuit breaker is turned on. *DO NOT MAKE ANY TRANSFORMER TAP CHANGES WITH THE POWER ON.*

3000 W LINE VOLTAGE CHANGEOVER INSTRUCTIONS

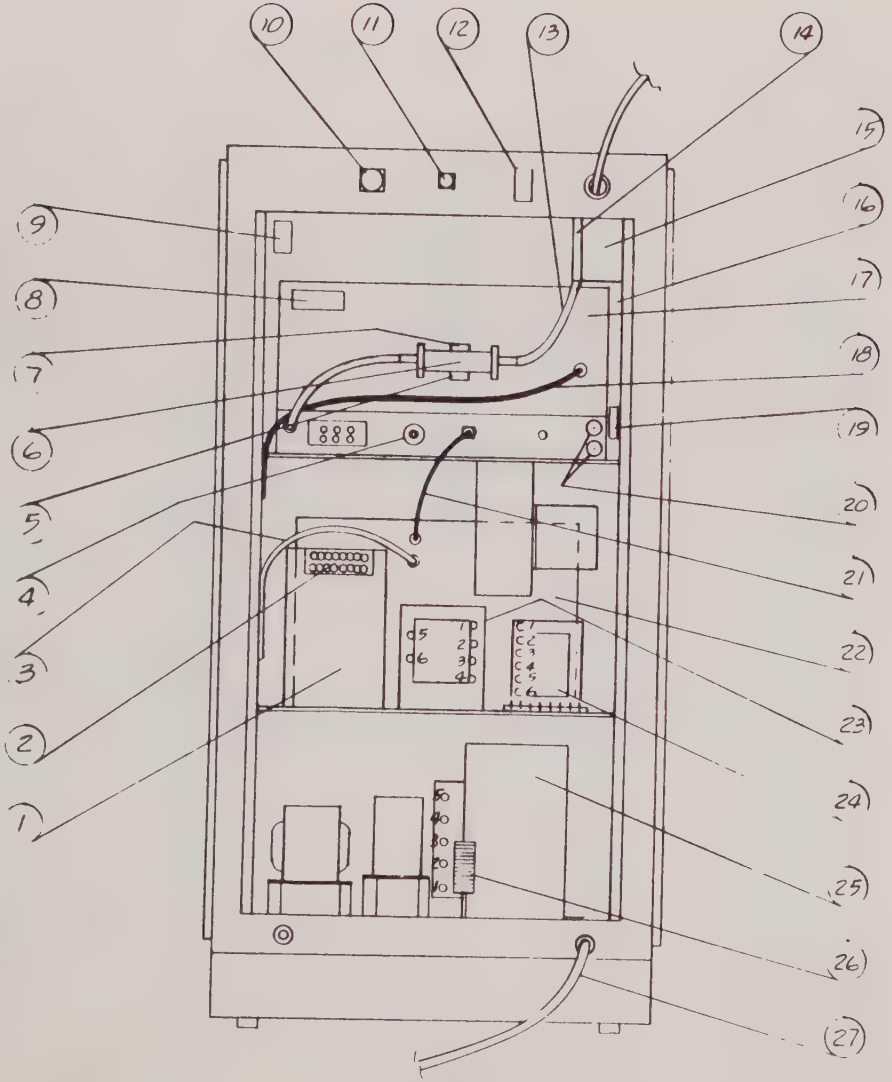
Follow instructions as outlined above. Use Figure 6 and 7 for component locations. The 3000 W generator uses two-plate transformers and the taps are adjusted as with the one-plate transformer used above for the 2000 W generator.

NOTE: Filament voltages are set .5 Vac higher than the published tube data to allow for voltage drop through the filament chokes.



27 L1
26 RY2
25 P2, Exciter Voltage Test Points
24 L8 PA Grid Adjustment
23 Exciter
22 1½A 3AG Plate Current Protect Fuse
21 Plate Calibration Pot For Test Box
20 Power Amplifier Load Control
19 Power Amplifier Final
18 Power Amlifier Tune Control
17 Grid Meter Test Jack With Shorting Plug
16 Grid Calibration Pot For Test Box
15 F2
14 F1
13 L5 PA Drive Control
12 Power Amplifier Load Control For Exciter
11 Power Amplifier Tune Control For Exciter
10 Crystal 6780 KC
9 L3 Oscillator
8 3A 3AG Control Fuse For Exciter
7 1/8A 8AG Screen Fuse For Exciter
6 Cathode Meter Test Points For Exciter
5 Grid Meter Test Points For Exciter
4 RY1
3 RY3
2 TB1
1 TB601

Figure 4. 2000 Watt Generator, Front View.



2000 WATT GENERATOR
REAR VIEW

27 Input Power Cord
26 Transient Suppressor
25 Plate Transformer
24 Filament Transformer for Final
23 Step Down Transformer
22 Exciter
21 R.F. Power Cable from Exciter to Final
20 Filament Power Input to Final
19 Rear Door Interlock
18 High Voltage Cable to Power Amplifier
17 Power Amplifier (Final) Deck
16 TB301
15 Flip Flop
14 TB100
13 R.F. Output Cable
12 SK103
11 SK102
10 SK101
9 TB101
8 Model & Serial Number Label
7 Bird 2500 Element (Forward Power)
6 Bird Sensor
5 Bird 250 W Element (Reflected Power)
4 SK201
3 High Voltage Cable to Exciter
2 TB502
1 Control Level Module

Figure 5. 2000 Watt RF Generator Rear View.

28 RY3
27 L1
26 Cathode, Meter Test Points For Exciter
25 Grid, Meter Test Points For Exciter
24 L8 PA Grid Adjustment
23 P2 Exciter Voltage Test Points
22 Power Amplifier Tune Control For Exciter
21 Power Amplifier Load Control For Exciter
20 Exciter
19 Plate Calibration Pot For Test Box
18 Power Amplifier Load Control
17 Power Amplifier Final
16 Power Amplifier Tune Control
15 2A 3AG Plate Current Protect Fuse
14 Grid Calibration Pot For Test Box
13 Grid Meter Test Jack With Shorting Plug
12 L4 PA Drive Control
11 F2
10 F1
9 Crystal 6780 KC
8 L3 Oscillator
7 3A 3AG Control Fuse For Exciter
6 1/8A 8AG Screen Fuse For Exciter
5 TB601
4 RY2
3 RY1
2 TB1
1 TB602

Figure 6. Front View 3000 Watt Generator.

Figure 7. 3000 Watt RF Generator Rear View.

TUNE AND LOAD SETTINGS

The power amplifier tune and load settings are marked on the final amplifier when tuned and shipped from Perkin-Elmer Ultek. The power generator has been tuned at the factory for correct operation into a 50-ohm load. The following procedure tunes the equipment into a 50-ohm load if required.

TEST EQUIPMENT REQUIREMENTS

Alignment, troubleshooting, and repair require monitoring internal voltages and currents. The RF output must be terminated into a load capable of accepting the rated output of the generator. In addition, this RF power must be measured; provisions are made on the rear apron of the generator to accept a remote metering box. This accessory (part number 145-008-800) is used for monitoring power amplifier tube current, grid current, final high voltage, and exciter high voltage.* Metering and calibration pots are located inside the generator. There is no need for an external plug to be connected to test socket SK103 when the fixture is removed. While we strongly recommend you use this meter test fixture, all test points are available within the generator to connect voltage and current measuring equipment. A typical test equipment hook-up is shown in Figure 8. Additional test equipment required:

1. Simpson multimeter #260 or equivalent
2. Tektronix 545 scope or equivalent with X 10 and high voltage probes
3. RF Load: Bird model 8890 or equivalent.
   Use "N" type connections through 2000 W and "HN" type for 3000 W.
4. Bird model 43 Wattmeter with suitable H series elements and adapters for "BNC", "N" or "HN" type RF connectors as required.

DISABLING INTERLOCKS AND FILAMENT IGNITER CIRCUIT

1. Remove the rear door. Defeat the magnetic interlock with a short clip lead or a small piece of magnet material.
2. Confirm that the rear two-pin MS connectors (SK102 A and B) are shorted.
3. Connect TB502-8 to TB 301-11 with a 15-inch long clip lead. See Figures 2 through 7 for location of TB points. Shorting these connections closes the external interlock loop of pins C and D in the remote control cable to the sputter head.
4. Remove filament control printed circuit card from the sputter head or disconnect either wire going to the filament igniter transformer terminals 1 or 2. Tape this wire if removed to prevent it from shorting. (The igniter transformer and the filament control printed circuit card are located in the sputter head). If this circuit is not disconnected during alignment of the generator the filament would be on continually. An alternate method would be to remove the filament.

* Exciter high voltage signal to test box only available in 3000 W generators.

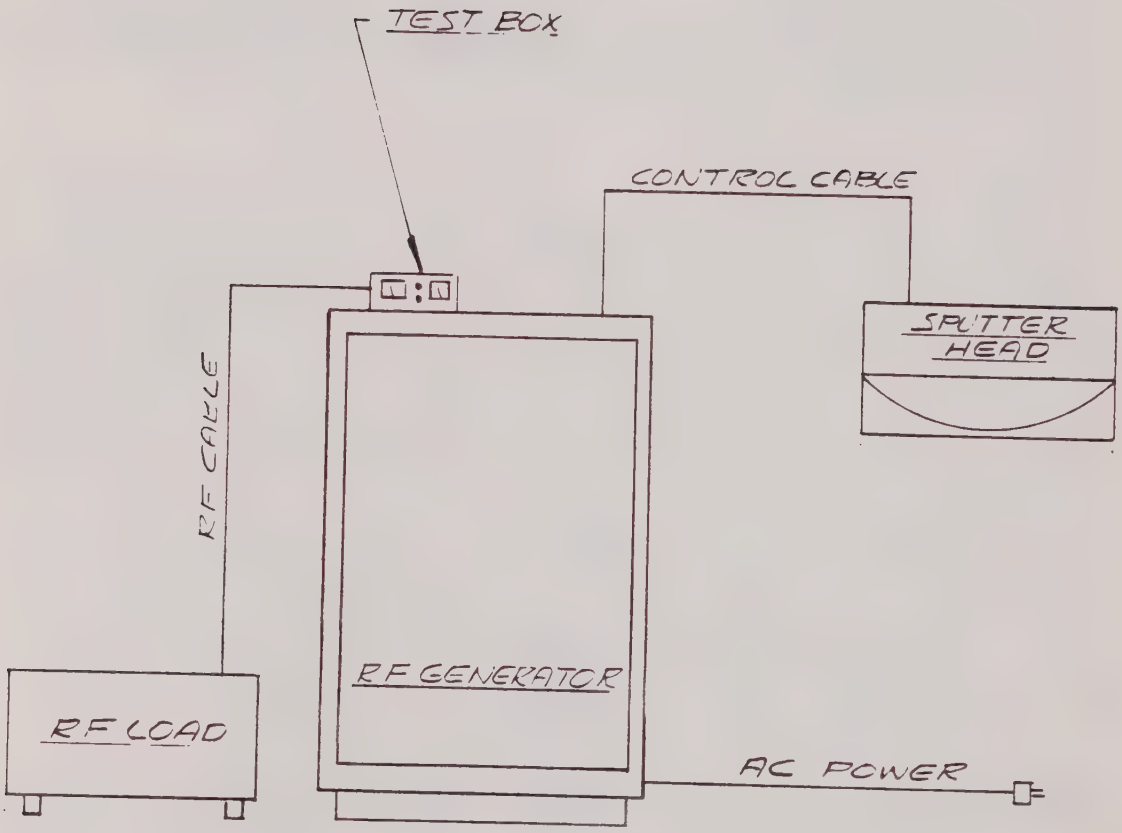


Figure 8. Typical Hookup of Test Equipment

POWER AMPLIFIER DECK ALIGNMENT

1. Turn the circuit breaker (on the front door of the power generator) ON and allow 90 seconds of warm-up.
2. Turn the power output control on the sputter head to minimum.
3. Turn the power generator's high voltage on by pushing the RF ON button*.
4. Using the accessory meter box, check the high voltage to the power amplifier section, power amplifier plate current (resting current), and the exciter high voltage. (See Table 4)
5. Open the front door of the power generator and set both the PA TUNE and PA LOAD (on the front panel of the power amplifier section) to 00.0**. If single turn knobs are used, set to 100.
6. Advance the power output control to produce a 100 mA increase in the plate current reading.
7. Adjust the PA TUNE control until the plate current shows a "dip" (resonance). The output power is shown on the FORWARD POWER meter on the sputtering head.
8. If needed, advance the power output slightly to produce an indication of grid current in the power amplifier section.
9. Turn the PA LOAD control clockwise to increase RF power output.
10. Readjust the PA TUNE control for minimum plate current.
11. Increase the power output control in small increments to produce successively higher PA grid current indications and power output.

Repeat steps 9 through 11 until desired output is obtained. The plate current should read as noted (or less) in Table 1 (depending on the line voltage at the operation location). At the rated output power, the load is adjusted for maximum power and the tune is adjusted for minimum plate current. At full load it may be difficult to observe a dip in plate current. Small adjustments of the TUNE control for maximum RF output can then be made.

TABLE 1. TYPICAL VOLTAGE AND CURRENTS

	HIGH VOLTAGE POWER AMPLIFIER SECTION	HIGH VOLTAGE EXCITER SECTION	PLATE CURRENT (resting current)	NOMINAL PLATE CURRENT AT FULL POWER	NEVER EXCEED PLATE CURRENT	GRID CURRENT AT FULL POWER
1000 W GENERATOR	3100 to 3400 Vdc	3100 to * 3400 Vdc	150 mA	≈500 mA	1.0 A	180 mA
2000 W GENERATOR	3900 to 4400 Vdc	½ OF THAT * MEASURED IN POWER AMPLIFIER	250 to 500 mA	900 mA	1.5 A	200 mA
3000 W GENERATOR	3900 to 4400 Vdc	3200 to * 3400 Vdc	250 to 500 mA	1.35 A	2 A	250 mA

*AUX METER TEST FIXTURE WILL ONLY MEASURE THIS VOLTAGE ON 3000 WATT GEN FROM SN 28107.

* Randex 3400 Sputtering Systems are turned on by a logic signal from a programmer.

**If only a minor alignment is required due to aging of components etc., it is not recommended that the TUNE and LOAD controls be set to 0. Only small adjustments from their present position will be required.

POWER AMPLIFIER CURRENT AND GRID METER ADJUSTMENT FOR THE TEST FIXTURE

All of the metering circuits in the generator have been factory calibrated and do not require adjustment unless their accuracy is suspect.

1. Plug the accessory meter box into the meter socket on the back apron of the generator.
2. Remove the back door of the generator. (See section 4 to close interlocks and defeat filament ignite circuit).

WARNING

DANGEROUS VOLTAGES ARE PRESENT INSIDE THE GENERATOR. BE VERY CAREFUL!

3. Insert a 0-2 A dc test meter in series with the high voltage lead between the power supply section and the power amplifier section. The negative lead of the test meter should be connected to the power amplifier section.

WARNING

THE TEST METER WILL BE 4000 V ABOVE GROUND POTENTIAL DURING THIS PROCEDURE. TAKE ALL NECESSARY PRECAUTIONS TO ENSURE SAFETY OF PERSONNEL.

4. Operate the power generator at its full rated power output and turn the plate meter adjustment potentiometer (on the front panel of the power amplifier section) until the test meter and the external meter box show the same readings.
5. Turn off the generator. CHECK TO SEE THAT THE HIGH VOLTAGE HAS DISCHARGED.
6. Remove the test meter and return the power generator to its original condition.

To adjust the power amplifier grid meter calibration:

1. Remove the shorted plug from the grid meter test jack (on the front panel of the power amplifier section).
2. Insert a 0-1 A dc test meter into the test point with the test meter positive connected to the inner conductor.
3. Operate the generator at or near its rated output and note the grid current value on the test meter.
4. WITHOUT moving the power output control, turn the high voltage off, remove the test meter, and replace the shorted phone plug into the test point.
5. Turn the high voltage back on and turn the grid meter adjustment potentiometer (on the front of the power amplifier section) until the metering box shows the same value of power amplifier grid current as noted on the test meter.

OVERLOAD TRIP POINT ADJUSTMENT

The overload protection circuit has been adjusted at the factory to switch off the high voltage power supply whenever the total power supply current exceeds a preset value. Adjustment isn't usually required. To set this adjustment:

1. Operate the power generator at maximum required output power and note the value of the plate current.
2. Turn the generator off.
3. The overload trip point should be set at a value 200 mA higher than the maximum expected plate current.
4. Place a 0-2 A meter in series with a variable dc bench-type power supply.
5. Connect one output of this supply to terminal 6 and the other to terminal 7 on TB502. (Location of TB502 can be found in Figures 3,5 and 7). The polarity of the power supply to these test points is unimportant.
6. With the generator off, increase the current from this test supply until the overload relay (RY2 in the control level section) closes.
7. If the current value is different from the desired trip point, move the slider on adjustable resistor R4 (in the control level section) until the trip point is correct. Be sure to tighten the clamp screw on this resistor after making the adjustment.

POWER AMPLIFIER SECTION INPUT NETWORK ADJUSTMENT

The input network of the power amplifier section has been adjusted at the factory and should not require readjustment. However, if the adjustment is suspect, proceed as follows.

1. Remove the back of the generator and defeat the interlock. See Section 4 to close remaining interlocks and defeat filament igniter circuit. Be careful – the high voltage is *is exposed and dangerous.*
2. Place an SWR meter* in the RF drive cable between the exciter section and the power amplifier section, keeping added coaxial leads as short as possible.
3. Remove the top of the power generator and then remove the perforated top of the power amplifier section.
4. Disengage the high voltage shorting strap from its normal position so that the high voltage is not shorted to ground.

WARNING

BE VERY CAREFUL WORKING AROUND THE EXPOSED POWER AMPLIFIER SECTION! LETHAL DC AND RF VOLTAGES ARE PRESENT.

5. Use a nut driver to loosen the locknut on the INPUT ADJ shaft; use an *insulated* tool to turn the shaft.
6. Operate the generator at its rated output while adjusting the shaft to produce a minimum reading on the SWR meter. The reflected power from the power amplifier section should be no greater than 15 W.

*Use a Bird Model 43 Wattmeter and 100 W H-series element.

7. Turn the generator off and ground all components in the power amplifier section using an insulated screwdriver.
8. Lock the INPUT ADJ shaft in place, being careful not to lose the adjustment.
9. Replace the perforated cover of the power amplifier section and check to see that the high voltage shorting strap is correctly positioned.
10. Return the generator to its original condition.

EXCITER ADJUSTMENT

The exciter has been aligned and tested at the factory for correct operation and should never require attention unless a component failure occurs. DO NOT attempt any exciter adjustments unless absolutely necessary. In all the adjustments described below, the power generator should be operated at its full rated output. The exciter PA TUNE control (on the front panel of the exciter section) should be adjusted to produce minimum exciter cathode current.

1. Insert a test meter (a Simpson 260, or equivalent) with a 500 mA dc scale into the CATHODE test jacks on the exciter front panel.
2. Use a screwdriver to adjust the PA TUNE control over a small range to produce a minimum reading on the test meter.
3. The exciter LOAD control (on the front panel of the exciter section) should be adjusted so that the full rated output of the power generator is obtained with the power output control at approximately 70% of maximum. This LOAD setting is a trade-off between excessive screen grid current at light loading and excessive plate dissipation (in the exciter power amplifier tube) at heavy loading. The PA LOAD capacitor should normally be very close to maximum capacity which corresponds to minimum loading. The oscillator, power amplifier drive, and power amplifier grid tank circuits should be adjusted to produce maximum possible exciter power amplifier grid current.
4. Insert a test meter (a Simpson 260, or equivalent) with a 1 mA dc scale into the GRID test jacks on the exciter front panel.
5. Loosen the locknuts on the slug shafts and adjust the oscillator slug, then the power amplifier drive and power amplifier grid. These adjustments should be repeated until no further increase in grid current is obtained.
6. Tighten the locknuts while being careful not to lose the adjustments. See Figures 3, 5 and 7 for location of these adjustments, and Table 2 for voltage and currents.

TABLE 2. EXCITER VOLTAGE AND CURRENTS

EXCITER USED IN	GRID CURRENT	CATHODE CURRENT *	POWER AMPLIFIER TUBE	POWER AMPLIFIER TUBE FILAMENT AND VOLTAGE	BIAS VOLTAGE	SCREEN VOLTAGE	MAX RF OUTPUT OF EXCITER
1000 W GENERATOR	ZERO AT MIN DRIVE 6 TO 8 mA AT 150 W EXCITER OUTPUT	ZERO AT MIN DRIVE 75 mA AT 150 W EXCITER OUTPUT	4-65 A	6.3 Vac AT 3.5 A	-120 Vdc LINE VOLTAGE DEPENDENT	+250 TO 300 Vdc LINE VOLTAGE DEPENDENT	150 W
2000 W GENERATOR	ZERO AT MIN DRIVE 8 mA AT 300 W EXCITER OUTPUT	ZERO AT MIN DRIVE 135 mA AT 300 W EXCITER OUTPUT	4-125A	5.0 Vac AT 5A	-135 Vdc LINE VOLTAGE DEPENDENT	+450 TO 600 Vdc LINE VOLTAGE DEPENDENT	300 W
3000 W GENERATOR	ZERO AT MIN DRIVE 7 mA AT 400 W EXCITER OUTPUT	ZERO AT MIN DRIVE 200 mA AT 400 W EXCITER OUTPUT	4-400 A	5.0 Vac AT 14A	-65 Vdc ZENER-REGULATED	+380 Vdc ZENER-REGULATED	400 W

*CATHODE CURRENT IS THE RESULTANT OF THE TOTAL PLATE CURRENT, SCREEN CURRENT AND GRID CURRENT

TABLE 3. GENERATOR FUSE AND CIRCUIT BREAKER AND AC LINE VOLTAGE AND CURRENT REQUIREMENTS

	EXCITER		FINAL POWER AMPLIFIER	AUX 117 Vac ON REAR APRON	CONTROL VOLTAGE	CIRCUIT BREAKER	LINE AND CURRENT
	CONTROL	SCREEN					
1000 W	3 AG 1½ A FASTBLOW	8 AG 1/16 A FASTBLOW	8 AG 1½ A FASTBLOW	NO FUSE	TWO 3 AG 3 A SLOWBLOW	2-POLE 25 A	1 Ø 208 - 240 V 25 A
2000 W	3 AG 3 A FASTBLOW	8 AG 1/8 A FASTBLOW	8 AG 1½ A FASTBLOW	NO FUSE	TWO 3 AG 5 A FASTBLOW	2-POLE 40 A	1 Ø 208 - 240 V 40 A
3000 W	3 AG 3 A FASTBLOW	8 AG 1/8 A FASTBLOW	8 AG 2 A FASTBLOW	3 AG 8 A FASTBLOW	TWO 3 AG 5 A FASTBLOW	2-POLE 50 A	1 Ø 208 - 240 V 50 A

DO NOT SUBSTITUTE FUSE VALUES

SYMPTOM	PROBLEM	REMEDY
No high voltage present; the RF ON light will not illuminate.	Protection interlock is open. Pins C and D on P 101, the remote control cable, do not have continuity.	Check water-flow switch. Check up-to-air (UTA) switch in sputter head. Check interlock switches on MODE and TARGET select. If you have a load Lock the control panel must be on. Replace the back door and/or install the interlock plug. Defective components in the control level section. Check that all cables are properly connected. Magnetic door switch(es) open.
No high voltage present; the RF ON light will not illuminate.	Protection interlock is closed. +12 to +20 Vdc can be measured from TB100 pin 2 (terminal board on the flip-flop circuit to ground).	Defective flip-flop circuit. Defective RF ON switch.
High voltage present. The RF ON light will not illuminate.	Defective lamp or LED.	Replace defective parts.
RF ON light illuminates. No high voltage.	Switching voltage is not present at the high voltage relays. The high voltage cable between the two power supply levels is disconnected.	Trace the control voltage circuit back to the flip-flop to determine the cause. Reconnect the plug.
The generator circuit breaker opens when the RF is switched on.	High voltage short	Check relays RY1, RY2, RY3 in the high voltage circuit for shorted contacts. Check operation of soft start circuit in High Voltage section of 2000 and 3000 W generators.
	The high voltage shorting strap in the power amplifier section is grounded.	Reposition the shorting strap.
	There is a short in the high voltage power supply section.	Trace the circuit and repair the short.
	There is a high voltage short in the exciter or power amplifier section.	Trace the circuit — repair the short.
	Defective plate transformer in the power supply section.	Replace the transformer.
The high voltage starts to come on but the circuit breaker trips.	The 600 W ballast resistor(R1) in the power supply section is loose.	Screw the resistor tightly into its socket (2000 and 3000 W generators only).

SYMPTOM	PROBLEM	REMEDY
The high voltage switches off before maximum output is obtained.	Generator not tuned correctly. Power amplifier draws excessvie plate current.	Refer to Section 4 for alignment instructions and Table 1 for maximum current requirement.
	Misadjusted R4 in the power supply section of the control level section.	Clean and readjust R4 as described in Section 4.
Excessive 120 Hz component in the generator output.	There is an open or shorted filter capacitor or other component in the exciter power supply.	Check for defective components in the power supply section of the exciter.
The low voltage circuits do not come on when the circuit breaker is turned on.	The air flow protection switch in the power amplifier section is not closing.	Check the power amplifier section blower and air flow switch.
	The interlock relay is not closing	Check the interlocks and the components in the control level.
	The interlock relay is closing, but the relay contacts are pitted and do not have good continuity.	Clean the contacts or replace the relay.
	ac input power (green lead) is not properly grounded (on 1000 W generators below SN24-117 and on 2000 W generators below SN 26-145.	Ground generator properly.
Low RF generator output.	ac input line voltage low.	Problem is external to the equipment.
	Weak tubes in the exciter section.	Check the tubes and replace if necessary.
	Exciter screen fuse is blown.	Determine the cause, then replace the fuse.
	Exciter is incorrectly tuned.	See Section 4.
	Power amplifier tube is weak.	Replace the tube, retune the generator; See Section 4.
	Power amplifier section is not tuned correctly.	See Section 4.
	Transformer taps are set for a higher line voltage.	See Section 3.
No generator output.	Fuse blown	Check all fuses to determine cause. See Table 3.
	Bad tube in the power amplifier section.	Replace the tube in the power amplifier section, retune the generator; see Section 4.
	Power amplifier cathode fuse is blown.	Determine the cause, replace the fuse.
	Power amplifier grid meter shorting plug is not inserted.	Replace the shorting plug.
	Exciter has no output.	Check the exciter.

SYMPTOM	PROBLEM	REMEDY
High voltage ARC in power amplifier section.	Shorted bypass or blocking capacitor in the power amplifier section.	Check for defective capacitor.
	The spark (ARC) gaps set too cloose.	Reset to .031.
Low voltage fuses F1 and F2 are blowing.	Shorted power amplifier filament transformer.	Replace defective transformer.
	Shorted power amplifier tube (filament short)	Replace power amplifier tube – retune as outlined in Section 4.
	Shorted power amplifier filament choke.	Replace power amplifier choke.
	Shorted bypass capacitors in the power amplifier.	Replace defective bypass capacitors in power amplifier.
	Shorted stepdown transformer in the control level section.	Replace defective transformer.
	Shorted auto/isolation transformer.	Replace defective transformer.
	Short external to generator.	Trace circuit from pins A and B in P101, the remote control cable; repair or replace as necessary.

1000 W GENERATOR LIST

	DESCRIPTION	PART NUMBER
B101	Blower: Cabinet top fan	122-012-100
SK101	Socket: For control cable	122-012-200
SK102	Socket: To water flow	122-012-300
SK103	Socket: For test fixture	122-012-400
SK401	Socket: Exciter section	122-012-600
TB301	Terminal Board: Interface	122-012-700
TB501	Terminal Board: Control level	122-012-800
TB502	Terminal Board: Control level	122-013-000
TB601	Terminal Board: Power supply	122-013-100
Power amplifier chassis		122-055-400
Flip-flop		721-037-000
Exciter deck		145-008-900
Control level		122-055-300
Power supply section		122-055-500
1000/2000 PGC cabinet		122-013-600
SK201	Socket: Power Amplifier section	122-012-500

1000 W POWER AMPLIFIER DECK PARTS LIST — DRAWING 221-121-800

	DESCRIPTION	PART NUMBER
ARC	Spark gap	122-013-700
B1	Blower	122-013-800
C1-C2	Capacitor: 1000 pf, 7.5 kV	122-014-400
C3	Capacitor: .0022 mf, 6 kV	122-014-500
C4-C5	Capacitor: 200 pf, 7.5 kV	133-273-500
C6	Capacitor Variable: Tune, 98 pf, 7 kV	145-007-000
C7	Capacitor Variable: Load 300 pf, 7 kV	145-004-200
C8	Capacitor: 100 pf, 7.5 kV	122-014-600
C9	Capacitor: 220 pf, 1000 V, 5%	122-014-700
C10	Capacitor: 150 pf, 1000 V, 5%	122-014-800
C11-C12	Capacitor: 110 pf, 1000 V, 5%	122-014-900
C13-C16	Capacitor: .01 mf, 600 V	122-015-000
C17-C19	Capacitor: .1 mf, 600 V	122-015-100
C19A	Capacitor: 2000 pf, 600 V	122-015-200
C20-C31	Capacitor: Same as C13	122-015-000
F1	Fuse: 1.5 A, 8 AG	122-015-300
L1	Inductor: Plate choke	122-015-400
L2	Inductor: Parasitic choke	122-015-600
L3	Inductor: Tank coil	122-015-700
L4	Inductor: L-section coil	122-015-800
L5	Inductor: RFC14	122-015-900
L6	Inductor: Input adjust coil	122-016-000
L7	Inductor: Filament choke	122-016-100

1000 WATT POWER AMPLIFIER PARTS LIST - (Continued)

	DESCRIPTION	PART NUMBER
P1	Plug	122-016-200
P2	Plug	122-016-300
R1-R2	Resistor: 150 ohm, 2 W, 10%	122-016-400
R3	Resistor: 100 ohm, 100 W, 5%	122-016-600
R4	Risistor: 10 k, 2 W, 10%	134-454-700
R5	Potentiometer: Plate current meter adjust, 1 k, 2 W	122-016-800
R6	Resistor: 220 ohm, 2 W, 10%	122-016-700
R7-R8	Resistor: .5 ohm, 10 W, 5%	122-016-900
S1	Switch: High voltage interlock	122-017-000
S2	Switch: Air flow	122-017-100
SK1	Socket: RF IN UG 290/U	122-017-200
BIRD	Power Sensor: Without elements	122-026-200
B	Power Sensor Element: 100 W	145-003-700
A	Power Sensor Element: 1000 W	145 003-600
	Power Sensor "N" adapters	145-007-700
	UG21 B/U "N" connector	140-242-900
TB1	Terminal board	122-017-400
TP1	Test point	122-017-500
V1	Tube: 3CX1000A7	145-003-800

1000 W AND 2000 W INTERFACE PARTS LIST – DRAWING B 221-122-700

	DESCRIPTION	PART NUMBER
S1	Switch Interlock	122-017-600
T1	Transformer, #76346	145 006-300

1000 W EXCITER PARTS LIST – DRAWING B 221-076-800

	DESCRIPTION	PART NUMBER
B1	Blower	122-017-700
C1-C10A	Capacitor: .01 mf, 600 V	122-017-800
C11-C12	Capacitor: 20 mf, 250 V	122-017-900
C13-C14	Capacitor: 16 mf, 450 V	122-018-000
C15	Capacitor: 10 pf, 500 V, 5%	122-018-100
C16	Capacitor: 220 pf, 500 V, 5%	122-018-200
C17-C18	Capacitor: Same as C1	122-017-800
C19	Capacitor: 150 pf, 500 V, 5%	122-018-400
C20	Capacitor: 100 pf, 500 V, 5%	122-018-500
C21-C24	Capacitor: Same as C1	122-017-800
C25	Capacitor: 47 pf, 1000 V 5%	122-018 600
C25A	Capacitor: Same as C1	122-017-800
C26	Capacitor: .01 mf, 1000 V	133-271-900
C27	Capacitor: Same as C1	122-017-800
C28	Capacitor: Same as C25	122-018-600
C29	Capacitor: .0022 mf, 6 kV	122-018-700
C30	Capacitor: 1000 pf, 5 kV	122 018-800
C31	Capacitor: 25 pf, 7.5 kV	122-018-900

1000 W EXCITER PARTS LIST – DRAWING B 221-076-800

	DESCRIPTION	PART NUMBER
C32	Capacitor, Variable: Air 500 pf, 800 V	122-019-100
C33-C34	Capacitor, 100 pf 5 kV	122-019-200
C35-C37	Capacitor: Same as C26	133-271-900
C38-C42	Capacitor: Same as C1	122-017-800
D1	Diode: BR820A	122-019-300
D2	Diode: BR44	122-019-400
F1	Fuse: 1.5 A, 3 AG	122-019-500
F2	Fuse: 1/16 A, 8 AG	122-019-600
L1	Inductor: 3 to 7 H #20C64	145-003-900
L2	Inductor: Choke, 2.5 mh	122-019-700
L3	Inductor: Oscillator coil	122-019-800
L4	Inductor: Same as L2	122-019-700
L5	Inductor: Power amplifier drive coil	122-019-900
L6	Inductor: Power amplifier output link	122-020-000
L7	Inductor: Power amplifier grid input link	122-020-100
L8	Inductor: Power amplifier grid coil	122-020-200
L9	Inductor: Plate choke	122-020-300
L10	Inductor: Variable: 0-5 μh	122-020-400
L11	Inductor: Parasitic choke	122-015-600
L12	Inductor: RF choke	122-020-500
L13	Inductor: Same as L2	122-019-700
P1	Plug	122-020-600
R1	Resistor: 10 ohm, 2 W, 10%	122-020-700
R2	Resistor: 220 ohm, 2 W, 10%	122-016-700
R3-R4	Resistor: 68 k, 1 W, 10%	122-020-800
R5	Resistor: 470 ohm, 2 W, 10%	122-020-900
R6	Resistor: 10 k, 2 W, 10%	134-454-700
R7-R8	Resistor: Not used	
R9	Resistor: 100 k, ½ W, 10%	122-021-000
R10	Resistor: 47 k, 2 W, 10%	122-021-100
R11	Resistor: 22 k, 1 W, 10%	122-021-200
R12	Resistor: 4.7 k, 1 W, 10%	122-021-300
R13	Resistor: 10 k, 2 W, 10%	134-454-700
R14	Resistor: Not used	
R15-R16	Resistor: 4.7 ohm, 1 W, 10%	122-021-400
R17	Resistor: 47 ohm, 1 W, 10%	122-021-600
R18	Resistor: 10 k, 20 W, 5%	122-021-700
R19	Resistor: 18 k, 2 W, 10%	122-021-800
R20	Resistor: 47 ohm, 2 W, 10%	122-021-900
R21	Resistor: 47 ohm, 2 W, 10%	122-022-000
SK1	Socket: High voltage, IN	122-022-100
SK2	Socket: RF OUT, UG 625 B/U	140-143-000
T1	Transformer: 7384	122-022-300
TB1	Terminal Board	122-022-400
TP1	Test Point	122-022-500
TP2	Test Point	122-022-500
V1	Tube: 6 AG7	145-006-600
V2	Tube: 2E26	145-006-500
V3	Tube: 4-65A	145-003-200
X1	Crystal: HC-6, 6780 KHz	145-005-700

1000 W CONTROL LEVEL PARTS LIST – DRAWING B 221-122-100

	DESCRIPTION	PART NUMBER
C1-C4	Capacitor: 1000 mf, 25 Vdc	122-022-700
C5	Capacitor: 20 mf, 250 Vdc	122-022-800
D1-D2	Diode: 2 A, 50 V	122-022-900
D3	Diode: GE 509	122-023-000
R1	Not Used	
R2	Resistor: 2K, 10 W, 5%	122-023-200
R3	Resistor: 470 ohm, 2 W, 10%	134-222-000
R4	Resistor, Adjustable: 15 ohm, 25 W, 5%	122-023-600
R5	Resistor: 200 ohm, 25 W, 5%	122-023-300
RY1	Relay: Interlock relay	122-023-700
RY2	Relay: Overload protect relay	122-023-800
T1	Transformer: Step-down T605	145-006-200
T2	Transformer: Power amplifier final tube filament #70512	145-005-000
T3	Transformer: #76346	145-006-300

1000 W POWER SUPPLY PARTS LIST – DRAWING B 221-128-500

	DESCRIPTION	PART NUMBER
C1	Capacitor: .1 mf, 7.5 kV	122-024-000
C2	Capacitor: 3.5 mf, 5 kV	122-024-100
CB1	Circuit breaker: 25 A	145-006-400
D1-D2	Diode: SDHD15K	136-161-100
D3	Diode: CE-240TS	122-024-200
F1-F2	Fuse: 3 A 3 AG, Slo-Blo	179-654-000
L1	Inductor: 11 H, at 800 mA	122-024-300
P1	Plug: Power amplifier high voltage	122-024-400
P2	Plug: Exciter High Voltage	122-024-500
PL1	Light: 327	179-747-000
R1-R3	Resistor: 20 k, 100 W, 5%	122-024-600
R4	Resistor: 10 k, 2 W 10%	134-454-700
R5-R9	Resistor: 2M 2 W 1%	122-024-700
RY1	Relay: Primary power relay	145-007-200
T1	Transformer: 70400	122-024-800
TB1	Terminal board	122-024-900

2000 W GENERÀTOR PARTS LIST

	DESCRIPTION	PART NUMBER
TB502	Terminal board: Control level	122-013-000
B101	Blower: Cabinet fan	122-012-100
SK101	Socket: For control cable	122-012-200
SK102	Socket: To water flow	122-012-300
SK103	Socket: For test fixture	122-012-400
SK201	Socket: Power amplifier section	122-012-500
SK401	Socket: Exciter section	122-012-600
TB301	Terminal board: Inerface section	122-012-700
TB501	Terminal board: Control level	122-012-800
TB601	Terminal board: Power supply	122-013-100
Power amplifier chassis		122-055-600
Flip-flop		721-037-000
RF exciter chassis		145-005-500
Control level		145-005-400
Power supply section		122-055-700
1000/2000 PGC cabinet		122-025-000

2000 W POWER AMPLIFIER PARTS LIST — DRAWING B 221-122-300

	DESCRIPTION	PART NUMBER
ARC	Spark gap	122-013-700
B1	Blower	122-013-800
C1-C2	Capacitor: 500 pf, 20 kV	122-025-200
C3	Capacitor: .0047 mf, 6 kV	122-025-300
C4-C5	Capacitor: 100 pf, 15 kV	122-025-400
C6	Capacitor variable: Tune, 100 pf, 10 kV	122-025-500
C7	Capacitor: 100 pf, 7.5 kV	122-014-600
C8	Capacitor variable: 300 pf Load	145-004-200
C9	Capacitor: 82 pf, 1000 V	122-025-600
C10	Capacitor: 91 pf, 1000 V	122-025-700
C11	Capacitor: 150 pf, 1000 V	122-015-800
C12	Capacitor: 100 pf, 1000 V	122-025-800
C13-C18	Capacitor: 01. mf, 1000 V	133-271-900
C19-C20	Capacitor: .5 mf, 50 V	122-025-900
C21	Capacitor: .1 mf, 600 V	122-015-100
C22	Capacitor: Same as C13	133-271-900
C23	Capacitor: 10 mf, 150 V	122-026-000
C24-C32	Capacitor: .01 mf, 600 V	122-017-800
C33	Capacitor: Same as C13	133-271-900
F1	Fuse: 1.5 A, 8 AG	122-015-300
L1	Inductor: Plate choke	122-015-400
L2	Inductor: Parasitic choke	122-015-600
L3	Inductor: Tank coil	122-015-700

2000 W POWER AMPLIFIER PARTS LIST -- DRAWING B 221-122-300 (cont'd.)

	DESCRIPTION	PART NUMBER
L4	Inductor: L-section coil	122-015-800
L5	Inductor: RF choke	122-015-900
L6	Inductor: Input adjust	122-016-000
L7	Inductor: Filament choke	122-016-100
P1	Plug	122 016-300
P2	Plug	122-016-200
R1	Resistor: 50 ohms, 150 W	145-005 900
R2	Resistor: 10 k, 2 W, 10%	134-454 700
R3	Potentiometer: Plate current meter adjust 1 k 2 W	122-016 800
R4	Resistor: 220 ohm, 2 W, 10%	122-016 700
R5	Resistor: 5 ohm, 10 W, 5%	122-016-900
R6	Resistor: 1 ohm, 25 W, 5%	122-026-300
R7	Resistor: 470 ohm, 2 W, 10%	122-020 900
R8	Potentiometer: Grid Current Meter Adjust, 2k, 2 W	122-026-400
S1	Switch: High voltage interlock	122-017-000
S2	Switch: Air flow	122-017-100
SK1	Socket: RF In UG 290/U	122-017-200
SK2	Socket: RF Out UG 58A/U	140-177-000
BIRD	Power sensor w/o elements	122-026-200
A	2500 W element	145-003-500
B	250 W element	145-003-100
TB1	Terminal board	122 107-400
TP1	Test point	122-017-500
V1	Tube: 3CX3000A7	145-004-900

1000 W AND 2000 W INTERFACE PARTS LIST – DRAWING B221-122-700

	DESCRIPTION	PART NUMBER
S1	Switch: Interlock	122-017-600
T1	Transformer: =76346	145-006 300

2000 W EXCITER PARTS LIST – DRAWING B 221-123-300

	DESCRIPTION	PART NUMBER
B1	Blower	122-017-700
C1-C10	Capacitor: .01 mf, 600 V	122-017-800
C11-C12	Capacitor: 16 mf, 450 Vdc	122-018-000
C13-C14	Capacitor: 20 mf, 250 Vdc	122-017-900
C15	Capacitor: 10 pf, 500 V, 5%	122-018-100
C16	Capacitor: 220 pf, 500 V 5%	122-018-200
C17-C18	Capacitor: Same as C1	122-017-800
C19	Capacitor: 150 pf, 500 V 5%	122-018-400
C20	Capacitor: 100 pf, 500 V 5%	122-018-500
C21-C22	Capacitor: Same as C1	122-017-800
C23	Capacitor: .01 mf	133-271-900

2000 W EXCITER PARTS LIST – DRAWING B 221-123-300 (cont'd.)

	DESCRIPTION	PART NUMBER
C24	Capacitor: 2000 pf, 600 V	122-015-200
C25	Capacitor: 47 pf, 1000 V, 5%	122-018-600
C26	Capacitor: Same as C23	133-271-900
C27	Capacitor: Same as C1	122-017-800
C28	Capacitor: Same as C25	122-018-600
C29	Capacitor: 0022 mf, 6 kV	122-018-700
C30	Capacitor: 1000 pf, 5 kV	122-018-800
C31	Capacitor: 25 pf, 7.5 kV	122-018-900
C32	Capacitor: variable: Air, 500 pf, 800 V	122-019-100
C33-C34	Capacitor: 100 pf, 5 kV	122-019-200
C35-C43	Capacitor: Same as C23	133-271-900
C50-C53	Capacitor: Same as C23	133-271-900
D1	Diode: SC1 FB2000	122-019-300
D2	Diode: SC1 FB 400	122-019-400
F1	Fuse: 3 A, 3 AG	122-056-400
F2	Fuse: 1/8 A, 8 AG	122-026-600
L1	Inductor: 20C64	145-003-900
L2	Inductor: RF choke, 2.5 mh	122-019-700
L3	Inductor: Oscillator coil	122-019-800
L4	Inductor: Same as L2	122-019-200
L5	Inductor: Power amplifier drive coil	122-019-900
L6	Inductor: Power amplifier drive output link	122-020-000
L7	Inductor: Power amplifier grid input link	122-020-100
L8	Inductor: Power amplifier grid coil	122-020-200
L9	Inductor: Plate choke	122-020-400
L10	Inductor variable: 0-5 μh	122-020-400
L11	Inductor: Parasitic choke	122-015-600
L12	Inductor: RF choke	122-020-500
L13	Inductor: Same as L2	122-019-700
P1	Plug	122-020-600
R1	Resistor: 10 ohm, 2 W, 10%	122-020-700
R2	Resistor: 220 ohm, 2 W, 10%	122-016-700
R3-R4	Resistor: 68 k, 1 W, 10%	122-020-800
R5	Resistor: 12.5 k, 20 W, 5%	122-026-700
R6	Resistor: 47 k, 2 W, 10%	122-021-100
R7	Resistor: 470 ohm 2W, 10%	122-020-900
R8	Resistor: 10 k, 2 W, 10%	134-454-700
R9	Resistor: 100 k, ½ W, 10%	122-021-000
R10	Resistor: Same as R6	122-021-100
R11	Resistor: 22 k 1 W, 10%	122-021-200
R12-R13	Resistor: Same as R8	134-454-700
R14	Resistor: 820 ohm 2 W, 10%	122-026-800
R15-R16	Resistor: 4.7 ohm, 1 W, 10%	122-021-400
R17	Resistor: 47 ohm, 1 W, 10%	122-021-600
R18	Resistor: 40 k, 20 W, 10%	122-026-900
R19	Resistor: 18 k, 2 W, 10%	122-021-800
R20-R21	Resistor: 150 ohm, 2 W, 10%	122-016-400
R22	Resistor: Same as R18	122-026-900
SK1	Socket: High voltage input	122-022-100

2000 W EXCITER PARTS LIST – B 221-123-300 (cont'd.)

	DESCRIPTION	PART NUMBER
SK2	Socket: RF Out UG 625V/U	140-143-000
T1	Transformer: 21F10	122-027-000
T2	Transformer: 21F04	122-027-200
T3	Transformer: 70545	122-027-300
TB1	Terminal board	122-022-400
TP1	Test point	122-022-500
TP2	Test point	122-022-500
V1	Tube: 6AG7	145-006-600
V2	Tube: 2E26	145-006-500
V3	Tube: 4-125A	145-003-300
X1	Crystal: HC-6, 6780 kHz	145-005-700

2000 W CONTROL LEVEL PARTS LIST – SERIAL NUMBER 26144 AND BELOW – DRAWING B221-124-200
2000 W CONTROL LEVEL SERIAL NUMBER 25145 AND ALL 3000 W CONTROL LEVELS – DRAWING B221-124-300

	DESCRIPTION	PART NUMBER
C1-C2	Capacitor: 1000 mf, 30 Vdc	122-022-700
C3	Capacitor: 20 mf, 250 Vdc	122-022-800
D1-D2	Diode: 2 A, 50 V	122-022-900
D3	Diode: GE 509	122-023-000
R1	Resistor: 10 ohm, 50 W, 5%	122-023-100
R2	Resistor: 2 K, 10 W, 5%	122-023-200
R3	Resistor: 470 ohm, 2 W, 10%	134-222-000
R4	Resistor, adjustable: 7.5 ohm, 25 W	145-046-000
R5	Resistor: 200 ohm, 20 W, 5%	122-023-300
RY1	Relay: Interlock relay	122-023-700
RY2	Relay: Overload protect relay	122-023-800
T1	Transformer: #T 605	145-006-200
T2	Transformer: #76484	145-005-200
T3-T4	Transformer: #76346	145-006-300

2000 W POWER SUPPLY PARTS LIST – DRAWING B221-076-900

	DESCRIPTION	PART NUMBER
C1-C2	Capacitor: .1 mf, 7.5 kV	122-024-000
C3-C5	Capacitor: 3.5 mf, 5000 V	122-024-100
CB1	Circuit breaker: 40 A	145-005-300
D1-D2	Diode: SDHD15K	136-161-100
D3	Diode: CE240TS	122-024-200
F1-F2	Fuse: 5 A, 3 AG	179-662-000
L1	Inductor: 11H, at 800 mA	122-024-300
L2	Inductor: 5 H at 200 mA	122-027-600
P1	Plug	122-024-500
PL1	Light: #327	179-747-000
R1	Ballast: 600 W	122-027-700

2000 W POWER SUPPLY PARTS LIST – DRAWING B221-076-900 (cont'd.)

	DESCRIPTION	PART NUMBER
R2-R5	Resistor: 20 k, 100 W, 5%	122-024-600
R6-R10	Resistor: 2 M, 2 W, 1%	122-024-700
R11	Resistor: 10 k, 2 W, 10%	134-454-700
RY1	Relay: HD11E	145-007-300
RY2	Relay: DMOF/12D.5	145-009-700
RY3	Relay: EM11E	145-007-200
SK1	Socket	122-027-800
T1	Transformer: H.V. #75448	145-006-000
TB1	Terminal board	122-024-900

3000 W GENERATOR PARTS LIST

	DESCRIPTION	PART NUMBER
B101	Blower: Cabinet fan top	122-012-100
F101	Fuse: 8 A, 3 AG	179-678-000
	Fuseholder: Accessory fuse 3 AG	122-028-100
SK101	Socket: for control cable	122-012-200
SK102	Socket: To water flow switch	122-012-300
SK103	Socket: For test fixture	122-012-400
SK104	Socket: To programmer stabilizer	140-143-000
SK201	Socket: Power amplifier section	122-012-500
SK401	Socket: Exciter section	122-012-600
TB301	Terminal board: Interface section	122-012-700
TB501	Terminal board: Control level	122-012-800
TB502	Terminal board: Control level	122-013-000
TB601	Terminal board: Power supply top level	122-013-100
TB602	Terminal board: Power supply bottom level	122-028-000
Power amplifier chassis		122-013-200
Flip-flop		721-037-000 or 220-998-000
Exciter chassis		145-005-500
Control level		145-005-400
Power supply section		122-013-500
3000 PGC cabinet		122-029-200

3000 W POWER AMPLIFIER DECK – DRAWING B 221-125-400

	DESCRIPTION	PART NUMBER
ARC	Spark gap	122-013-700
B1	Blower	122-013-800
C1-C2	Capacitor: 500 pf, 20 kV	122-025-200
C3	Capacitor: Not used	
C4-C5	Capacitor: 100 pf, 15 kV	133-272-300
C6	Capacitor, Variable: 100 pf, 10 kV	122-025-500
C7	Capacitor: Not used	
C8	Capacitor, variable: 250 pf, 10 kV	122-028-300
C9	Capacitor: 82 pf, 1000 V, 5%	122-025-600

3000 W POWER AMPLIFIER DECK – DRAWING B221-125-400 (cont'd)

	DESCRIPTION	PART NUMBER
C10	Capacitor: 91 pf, 1000 V, 5%	122-025-700
C11	Capacitor: 150 pf, 1000 V, 5%	122-014-800
C12	Capacitor: 100 pf, 1000 V, 5%	122-025-800
C13-C18	Capacitor: .01 mf, 1000 V	133-271-900
C19-C20	Capacitor: .5 mf, 50 V	122-025-900
C21	Capacitor: .1 mf, 600 V	122-015-100
C22	Capacitor: Same as C13	133-271-900
C23	Capacitor: 10 mf, 150 Vdc	122-026-000
C24-C33	Capacitor: .01 mf, 1000 V	133-271-900
F1	Fuse: 2 A, 8 AG	122-028-400
	Fuseholder: 8 AG	122-028-500
L1	Inductor: Plate choke	122-015-400
L2	Inductor: Parasitic choke	122-015-600
L3	Inductor: Tank coil	122-015-700
L4	Inductor: L-section coil	122-015-800
L5	Inductor: RF choke	122-015-900
L6	Inductor: Input adjust coil	122-016-000
L7	Inductor: Filament choke	122-016-100
P1	Plug: High voltage input	122-016-300
P2	Plug: Power amplifier section	122-016-200
R3	Potentiometer: 1 K, 2 W	122-016-800
R4	Resistor: 220 ohm, 2 W, 10%	122-016-700
R5	Resistor: .5 ohm, 10 W, 5%	122-016-900
R6	Resistor: 1 ohm, 25 W, 5%	122-026-300
R7	Resistor: 470 ohm, 2 W, 10%	122-020-900
R8	Potentiometer: 2 k 2 W	122-026-400
R9	Potentiometer: 20 k, 2 W	122-028-700
SK1	Socket RF, IN UG290/U	122-017-200
SK2	Socket RF, Out UG560/U	140-251-000
S1	Switch	122-017-000
S2	Switch	122-017-100
BIRD	Power sensor w/o elements	122-026-200
A	Power sensor element 2500 W	145-003-100
B	Power sensor element 250 W	145-003-500
	Power sensor "HN" adapter	145-007-400
	UG494 A/U "HN" connector	140-309-000
TB1	Terminal board	122-017-400
TP1	Test point	122-017-500
V1	Tube: 3CX3000A7	145-004-900

3000 W INTERFACE PARTS LIST – DRAWING B221-125-500

	DESCRIPTION	PART NUMBER
S1	Switch	122-017-600
T1	Transformer #76346	145-006-300

3000/5000 W EXCITER PARTS LIST – DRAWING B221-124-400

	DESCRIPTION	PART NUMBER
B1	Blower	122-017-700
C1-C11	Capacitor: .01 mf, 600 V	122-017-800
C12-C13	Capacitor: 16 μf, 450 V	122-018-000
C14-C15	Capacitor: 20 μf, 250 V	122-017-900
C16	Capacitor: Same as C1	122-017-800
C17	Capacitor: 10 pf, 500 V, 5%	122-018-100
C18	Capacitor: 220 pf, 500 V, 5%	122-018-200
C19-C20	Capacitor: Same as C1	122-017-800
C21	Capacitor: 150 pf, 500 V, 5%	122-018-400
C22	Capacitor: 100 pf, 500 V, 5%	122-018-500
C23-C24	Capacitor: Same as C1	122-017-800
C25	Capacitor: 47 pf, 1000 V, 5%	122-018-600
C27-C29	Capacitor: Same as C1	122-017-800
C30	Capacitor: Same as C25	122-018-600
C31	Capacitor: .01	133-271-700
C32	Capacitor: .0022 mf, 6 kV	122-018-700
C33	Capacitor: 1000 pf, 5 kV	122-018-800
C34	Capacitor: 25 pf, 7.5 kV	122-018-900
C35	Capacitor, variable: 500 pf, 800 V	122-019-100
C36-C37	Capacitor: 100 pf, 5 kV	122-019-200
C38-C53	Capacitor: Same as C1	122-017-800
C54	Capacitor: 2000 pf, 600 V	122-015-200
D1	Diode: BR 82A	122-019-300
D2	Diode: BR 44	122-019-400
D3-D4	Diode: In 3349B	122-028-900
D5-D6	Diode: In 5364B	122-029-000
F1	Fuse: 3 A, 3 AG	122-056-400
	Fuseholder: 3 AG	122-028-100
F2	Fuse: 1/8 A, 8 AG	122-026-600
	Fuseholder: 8 AG	122-028-500
L1	Inductor: 20 C64	145-003-900
L2	Inductor: 2.5 mh	122-019-700
L3	Inductor: Oscillator coil	122-019-800
L4	Inductor: Power amplifier drive coil	122-019-900
L5	Inductor: Power amplifier drive coil link	122-020-000
L6	Inductor: Power amplifier grid coil input link	122-020-100
L7	Inductor: Power amplifier grid coil	122-020-200
L8	Inductor: Same as L2	122-019-700
L9	Inductor: Plate choke	122-030-300

3000/5000 W EXCITER PARTS LIST B 221-124-400 (cont'd.)

	DESCRIPTION	PART NUMBER
L10	Inductor, variable: 0-5 μh	122-020-400
L11	Inductor: RF choke	122-020-500
L12	Inductor: Parasitic suppressor choke	122-015-600
L13	Inductor: Same as L2	122-019-700
P1	Plug	122-020-600
R1-R2	Resistor: 68 k, 1 W, 10%	122-020-800
R3	Resistor: 12.5 k, 20 W, 5%	122-026-700
R4	Resistor: 47 k, 2 W, 10%	122-021-100
R5	Resistor: 220 ohm, 2 W, 10%	122-016-700
R6	Resistor: 470 ohm, 2 W, 10%	122-020-900
R7	Resistor: 10 k, 2 W, 10%	134-454-700
R8-R9	Resistor: 1 k, 50 W, 5%	134-043-000
R10	Resistor: 100 k, ½ W, 10%	122-021-000
R11	Resistor: Same as R4	122-021-100
R12	Resistor: 22 k, 1 W, 10%	122-021-200
R13-R14	Same as R7	134-454-700
R15	Resistor: 47 ohm, 1 W, 10%	122-021-600
R16	Resistor: 40 k, 20 W, 5%	122-026-900
R17	Resistor: 39 k, 2 W, 10%	122-029-200
R18	Resistor: 1.5 k, 5 W, 5%	122-029-300
R19-R20	Resistor: 4.7 ohm, 1 W, 10%	122-021-400
R21-R22	Resistor, 150 ohm, 2 W, 10%	122-016-400
R23	Resistor: 40 k, 20 W, 5%	122-026-900
R24	Resistor: 10 ohm, 2 W, 10%	122-020-700
SK1	Socket: High voltage input	122-022-100
SK2	Socket: RF Out, UG625B/U	140-143-000
SK3	Socket: 8-Pin	140-089-000
T1	Transformer: 26F66	145-006-100
T2	Transformer: 21F10	122-027-000
T3	Transformer: 70545	122-027-300
TB1	Terminal Board	122-022-400
TP1	Test points	122-022-500
TP2	Test points	122-022-500
V1	Tube: 6AG7	145-006-600
V2	Tube: 2E26	145-006-500
V3	Tube: 4-400A	145-005-600
X1	Crystal: HC-6, 6780 kHz	145-005-700

2000 W CONTROL LEVEL, SERIAL NUMBERS 26145 AND ABOVE AND 3000 W CONTROL LEVEL – DRAWING B221-124-300

	DESCRIPTION	PART NUMBER
C1-C2	Capacitor: 1000 mf, 30 Vdc	122 022-700
C3	Capacitor: 20 mf, 250 V	122-022-800
D1-D2	Diode: 2 A, 50 V	122-022-900
D3	Diode: GE 509	122-023-000
R1	Resistor: 10 ohm, 50 W, 5%	122-023-100
R2	Resistor: 2 k, 10 W, 5%	122-023-200
R3	Resistor: 470 ohm, 2 W 10%	134-222-000
R4	Resistor, adjustable: 7.5 ohm, 25 W, 5%	145-004-600
R5	Resistor: 200 ohm, 20 W, 5%	122-023-300
RY1	Relay: Interlock relay	122-023-700
RY2	Relay: Overload relay	122-023-800
T1	Transformer: T605	145-006-200
T2	Transformer: #76484	145-005-200
T3, T4	Transformer: #76346	145-006-300

3000 W POWER SUPPLY – DRAWING B 221-077-300

	DESCRIPTION	PART NUMBER
C1-C3	Capacitor: .1 mf, 7500 V	122-024-000
C4	Capacitor: 6.25 mf, 8000 V	122-029-600
C5-C6	Capacitor: 3.5 mf, 5000 V	122-024-100
CB1	Circuit breaker: 50 A	122-029-700
D1	Diode: CE240TS	122-029-800
D2-D5	Diode: SDHD 15 k	136-161-100
D6	Diode: SDHD 10 k	136-406-300
F1-F2	Fuse: 5 A, 3 AG	179-662-000
	Fuseholder: 3 AG	122-029-900
L1	Indicator: Filter choke, 11 H	122-024-300
L2	Inductor: Filter choke, 5 H	122-027-600
P1	Plug	122-024-400
P2	Plug	122-024-500
P3	Plug	122-024-500
PL1	Pilot light: #327	179-747-000
R1	Resistor: Ballast, 600 W	122-027-700
R2-R5	Resistor: 20 k, 100 W, 5%	122-024-600
R6	Not used	
R7-R11	Resistor: 2 M, 2 W, 1%	122-024-600
R12	Besistor: 10 k, 2 W, 10%	134-454-700
R13-R14	Resistor: 100 k, 50 W, 5%	134-041-000
R15	Resistor: Same as R12	134-454-700
R16-R20	Resistor: Same as R7	122-024-600
RY1	Relay: HD11E	145-007-300
RY2	Relay: DMOF/12D.5	145-004-700

3000 W POWER SUPPLY – DRAWING B 221-077-300 (cont'd.)

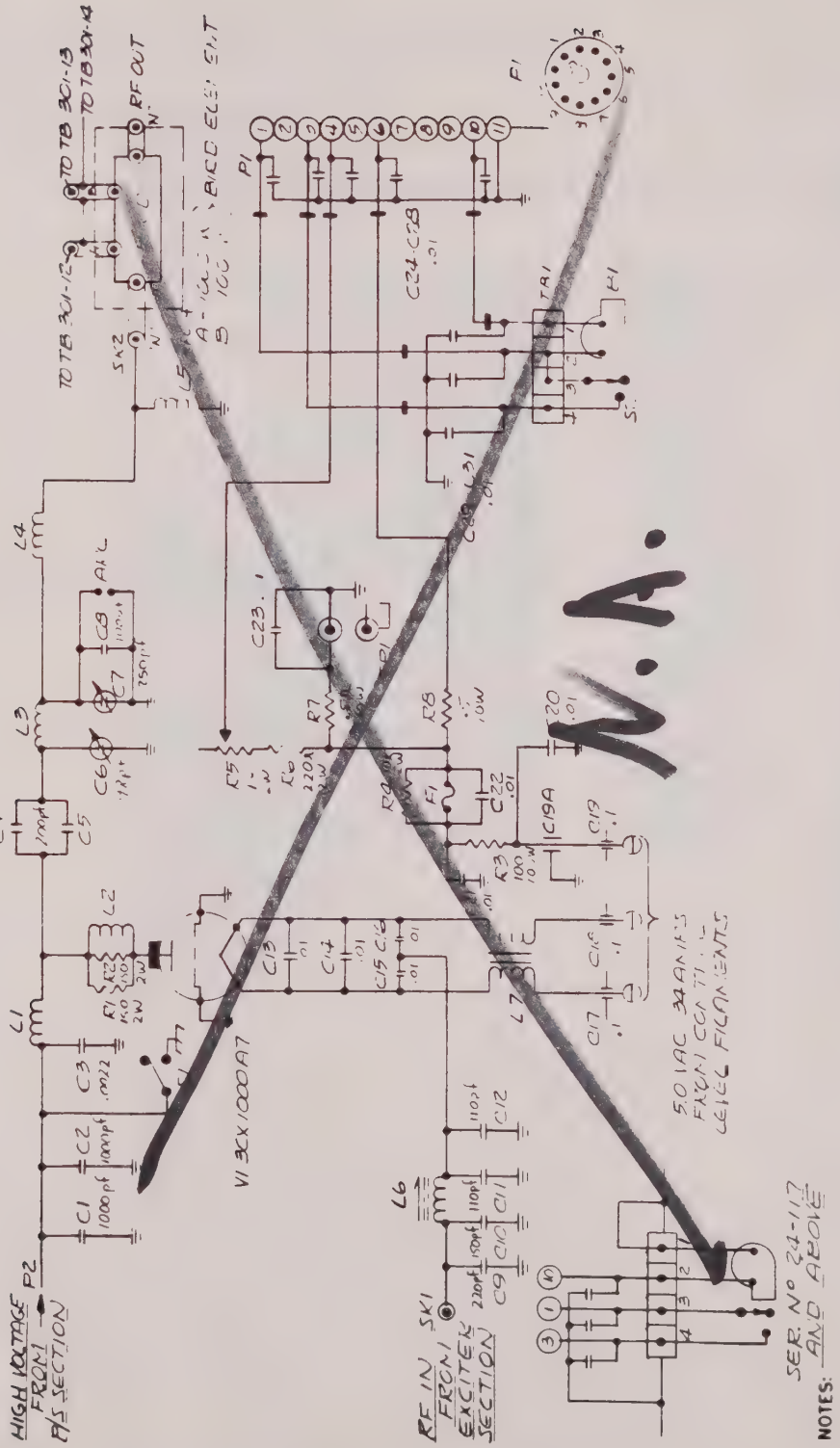
	DESCRIPTION	PART NUMBER
RY3	Relay: EM11E	145-007-200
SK1	Socket: Power amplifier	122-027-800
SK2	Socket	122-022-100
SK3	Socket	122-027-800
T1-T2	Transformer: #75448	145-006-000
TB1	Terminal board	122-024-900

MISCELLANEOUS PARTS LIST

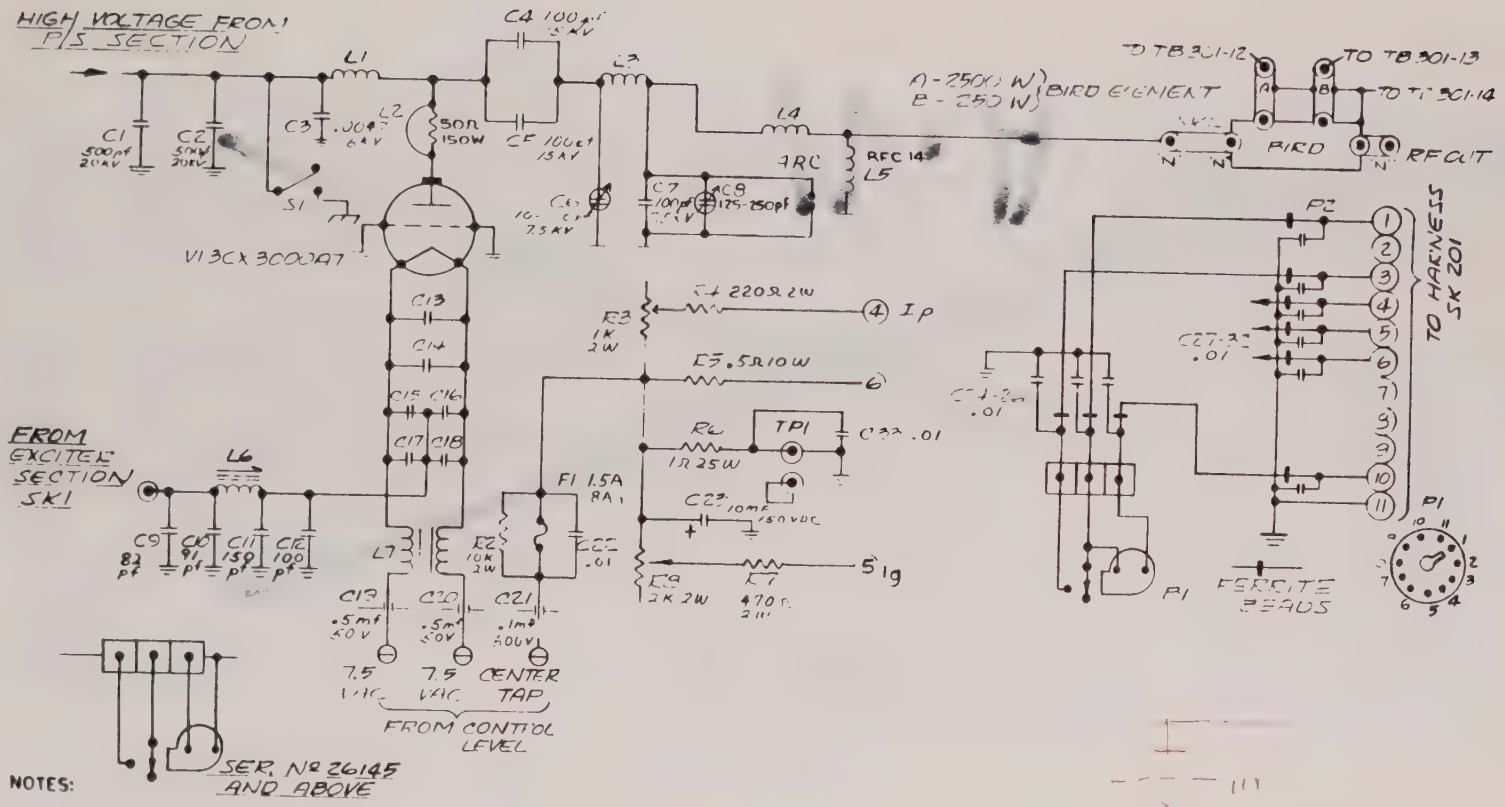
DESCRIPTION	PART NUMBER
50 A, ac plug	121-962-300
30 A, ac plug	139-901-000
Right-angle HN adapter	178-151-700
MS connector for water flow switch	139-989-000
Clamp for MS connector	139-990-000
RF connector, UG21B/U	140-242-900
RF connector, UG494/U	140-309-000
RF connector, UG625B/U	140-143-000
RF connector, UG58A/U	140-177-000
RF connector, UG560/U	140-251-000
Fuse 3A 3AG slo-blo	179-654-000
Fuse 1.5A 8AG Fast-Blo	122-015-300
Fuse 1/8A 8AG Fast-Blo	122-026-600
Fuse 1.5A 3AG Fast-Blo	122-019-500
Fuse 1/16A 8AG Fast-Blo	122-019-600
Fuse 2A 8AG Fast-Blo	122-028-400
Fuse 5A 3AG Fast-Blo	179-662-000
Fuse 8A 3AG Fast-Blo	179-678-000
Fuse 3A 3AG Fast-Blo	122-056-400

This section contains the following schematics and assembly drawings:

B 221-121-800	1000 W Power Amplifier Section
B 221-123-300	2000 W Power Amplifier Section
B 221-125-400	3000 W Power Amplifier Section
B 221-076-800	1000 W Exciter Section
B 221-122-300	2000 W Exciter Section
B 221-124-400	3000/5000 W Exciter Section
B 221-128-500	1000 W Power Supply Section
B 221-076-900	2000 W Power Supply Section
B 221-077-300	3000 W Power Supply Section
B 221-122-100	1000 W Control Level
B 221-124-200	2000 W Control Section Below SN 26-144
B 221-124-300	2000 W Control Section SN 26-145 and Above and All 3000 W
B 221-122-700	1000 W/2000 W Interface Section
B 221-125-500	3000 W Interface Section
B 221-044-500	Flip-Flop Schematic for MHTL Logic
B 720-171-000	Flip-Flop Schematic
C 221-126-400	Harness Interconnect, 1000 W/2000 W
B 221-126-500	Harness Interconnect, 3000 W
B 720-162-000	Cable Interconnect
B 721-058-000	Cable RF, 0 through 2 kW
B 138-516-000	Cable RF, 0 through 3 kW



B 221-121-800 1000 W Power Amplifier Section

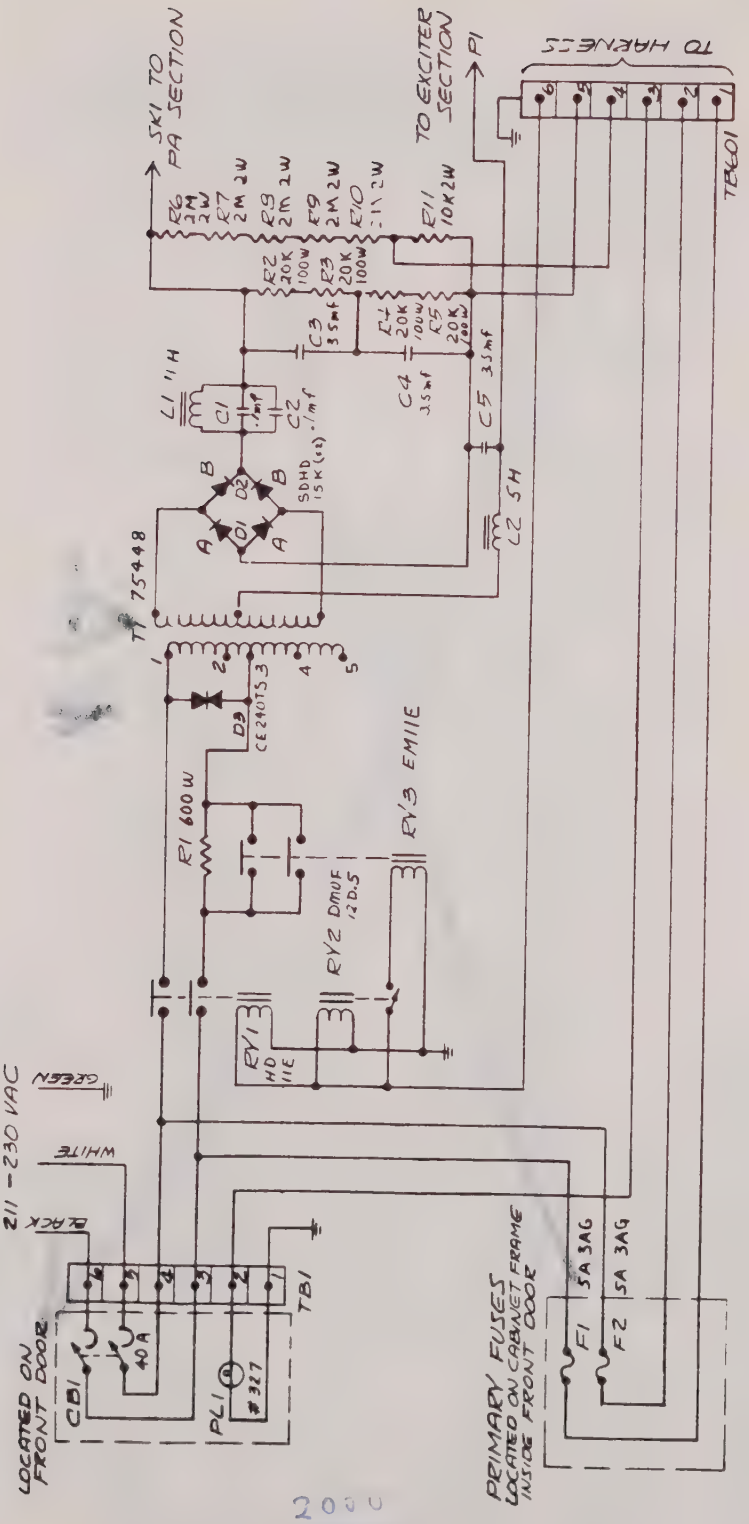

HIGH VOLTAGE FROM P/S SECTION
L1
C4 100pf 15KV
L3
L4
C1 500pf 20KV
C2 50MV 20KV
C3 .001mf 6KV
L2
50R 150W
CF 100pf 15KV
ARC
REC 14
L5
A - 250 W
B - 250 W
BIRD ELEMENT
TO TB301-12
TO TB301-13
TO TB301-14
BIRD
RFOUT
S1
V13CX3000A7
C7 10mf
C8 175-250pf
C13
C14
C15 C16
C17 C18
R3 1K 2W
R4 220Ω 2W
Ip
R5 .5Ω 10W
6
R6 1R 25W
TP1
C22 .01
C23 10mf 150VDC
FROM EXCITER SECTION SK1
L6
C9 82 pf
C10 91 pf
C11 150 pf
C12 100 pf
L7
R2 10K 2W
F1 1.5A 8A
C24 .01
R8 2K 2W
R7 470Ω 2W
5 Ig
C19 .5mf 50V
C20 .5mf 50V
C21 .1mf 600V
7.5 VAC
7.5 VAC
CENTER TAP
FROM CONTROL LEVEL
P2
C27-32 .01
C24-26 .01
TO HARNESS SK 201
P1
FERRITE BEADS
SER. NR 26145 AND ABOVE
NOTES:

B 221-125-400 3000 W Power Amplifier Section

B 221-076-800 1000 W Exciter Section

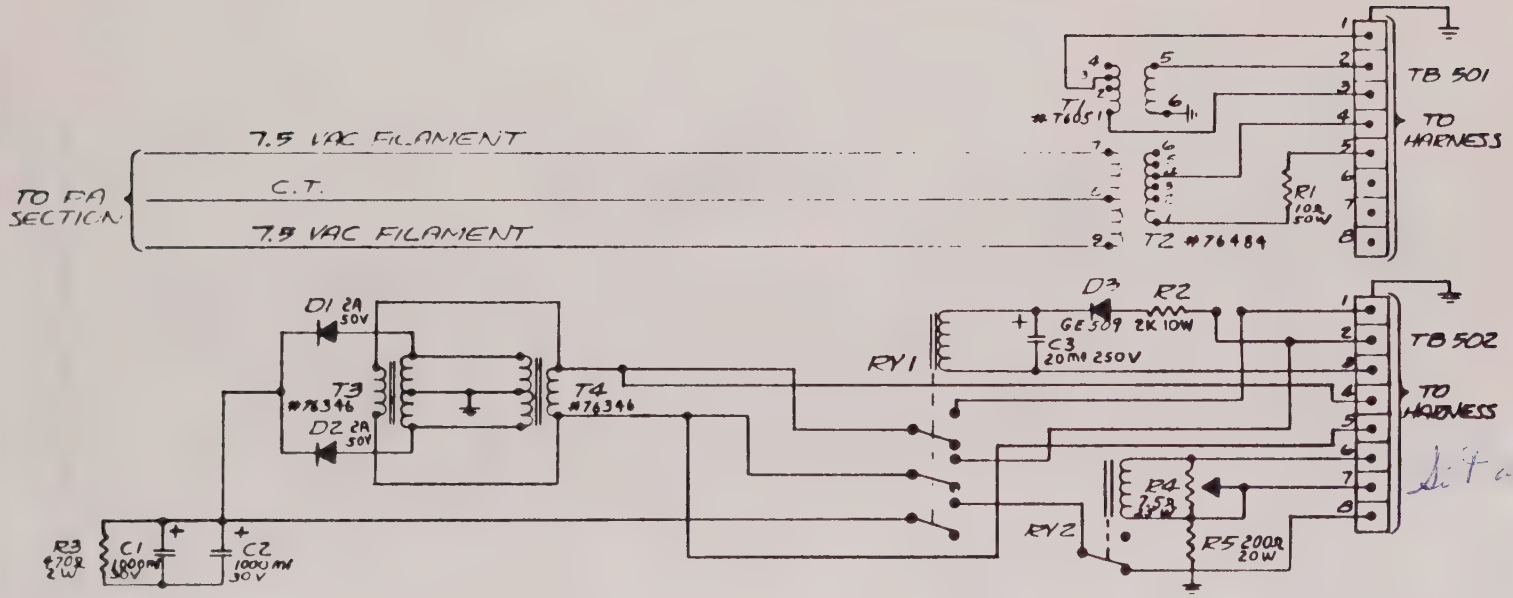
B 221-122-300 2000 W Exciter Section

B 221-124-400 3000/5000 W Exciter Section



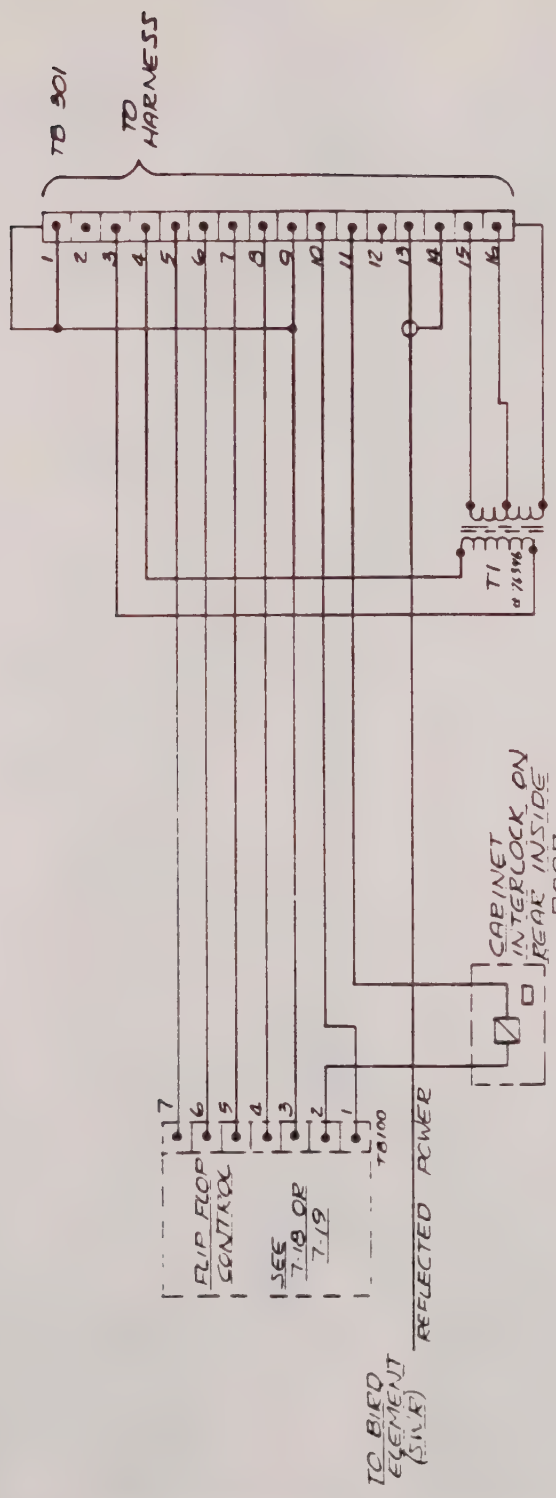
2000

B 221-128-500 [redacted] Power Supply Section

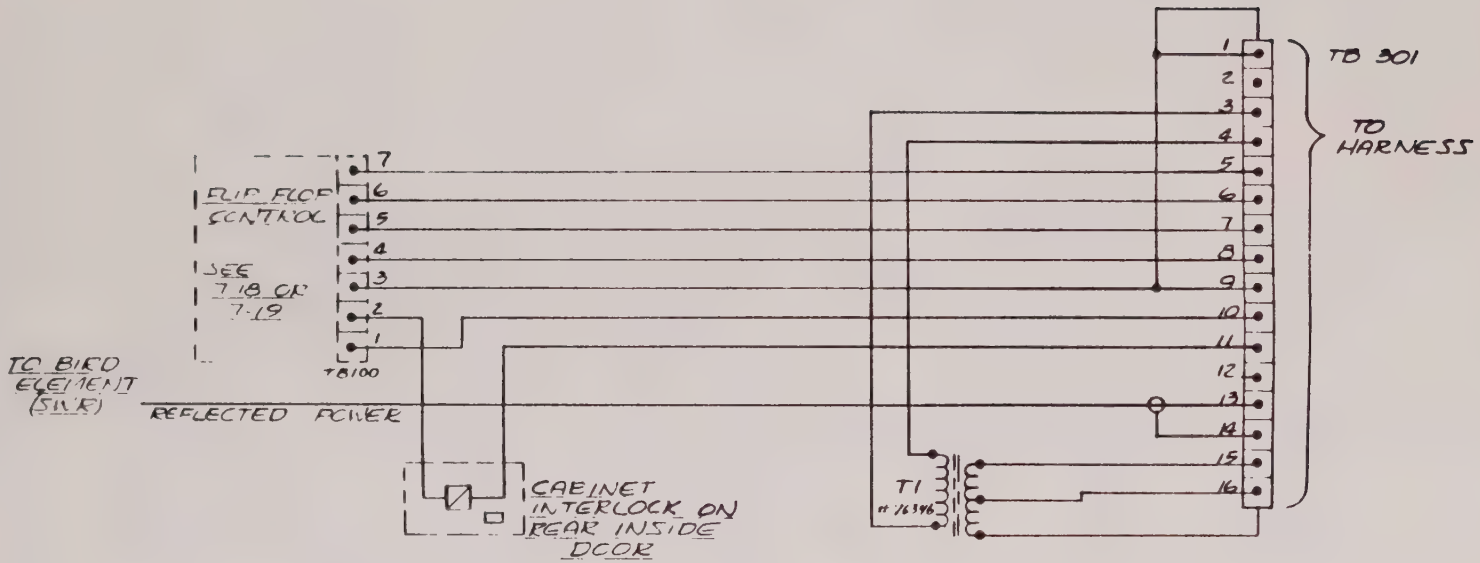


ALL 2000 W GEN'. SER. Nº 26145 AND ABOVE, AND ALL 3000 W. GEN. CONTROL SECTIONS

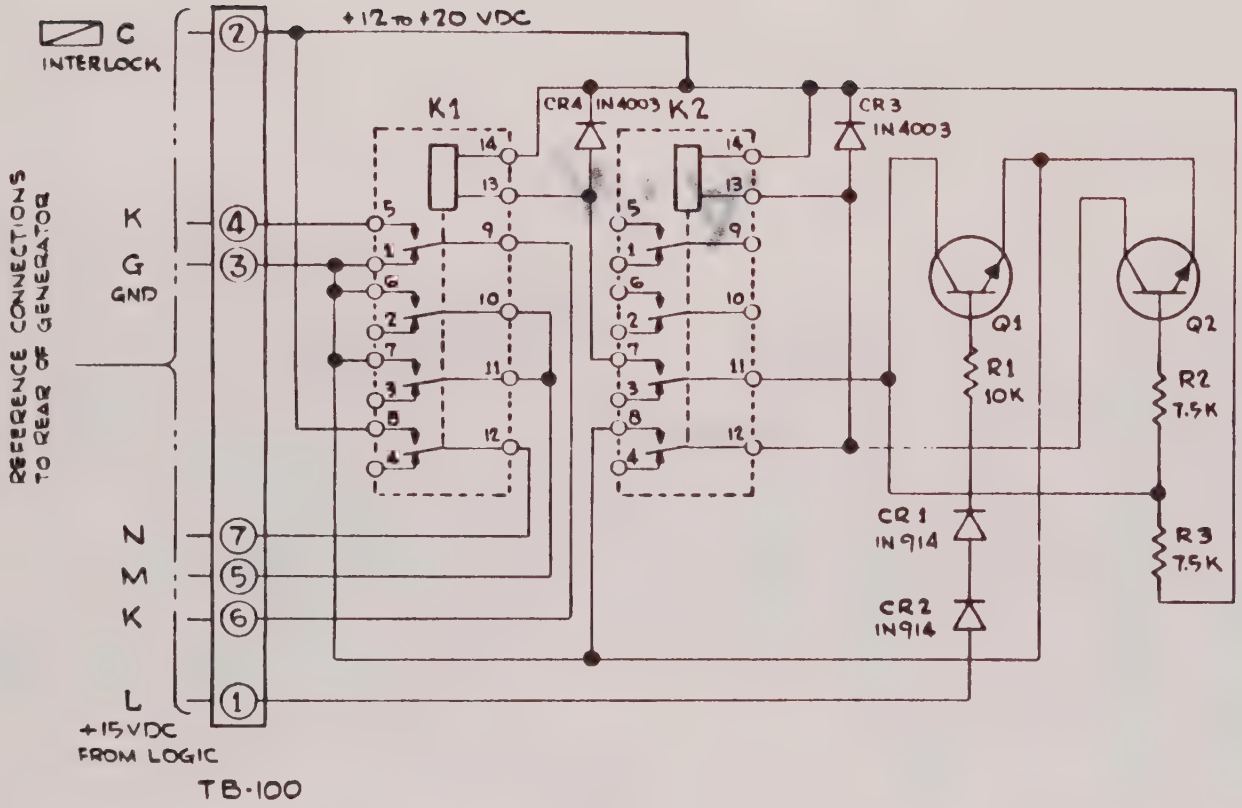
NOTES:



B 221-122-700 1000 W/2000 W Interface Section

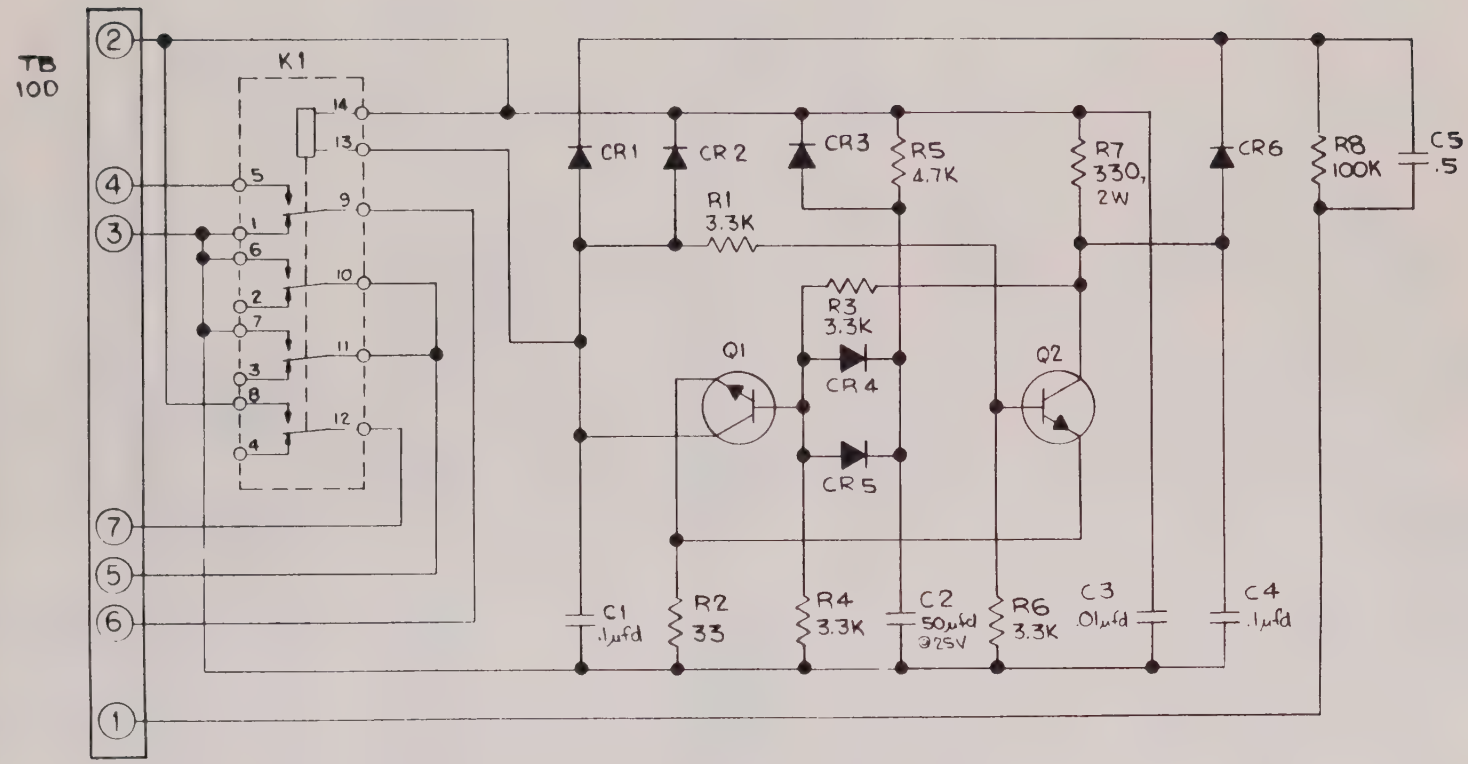

FLIP FLOP CONTROL
SEE 7.18 OR 7.19
7
6
5
4
3
2
1
TB100
TO BIRD ELEMENT (SWR)
REFLECTED POWER
CABINET INTERLOCK ON REAR INSIDE DOOR
T1
#16396
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
TO 301
TO HARNESS

N.A.



NOTE: K2 ENERGIZED BY INTERLOCK CIRCUIT
K1 ENERGIZED BY HIGH (1) LOGIC LEVEL FROM PROGRAMMER

3. ALL VOLTAGES ARE FOR TEST PURPOSES.
2. ALL TRANSISTORS ARE 2N4401
1 ALL VALUES ARE IN OHMS, AND 1/4 W
NOTES: (UNLESS OTHERWISE SPECIFIED)

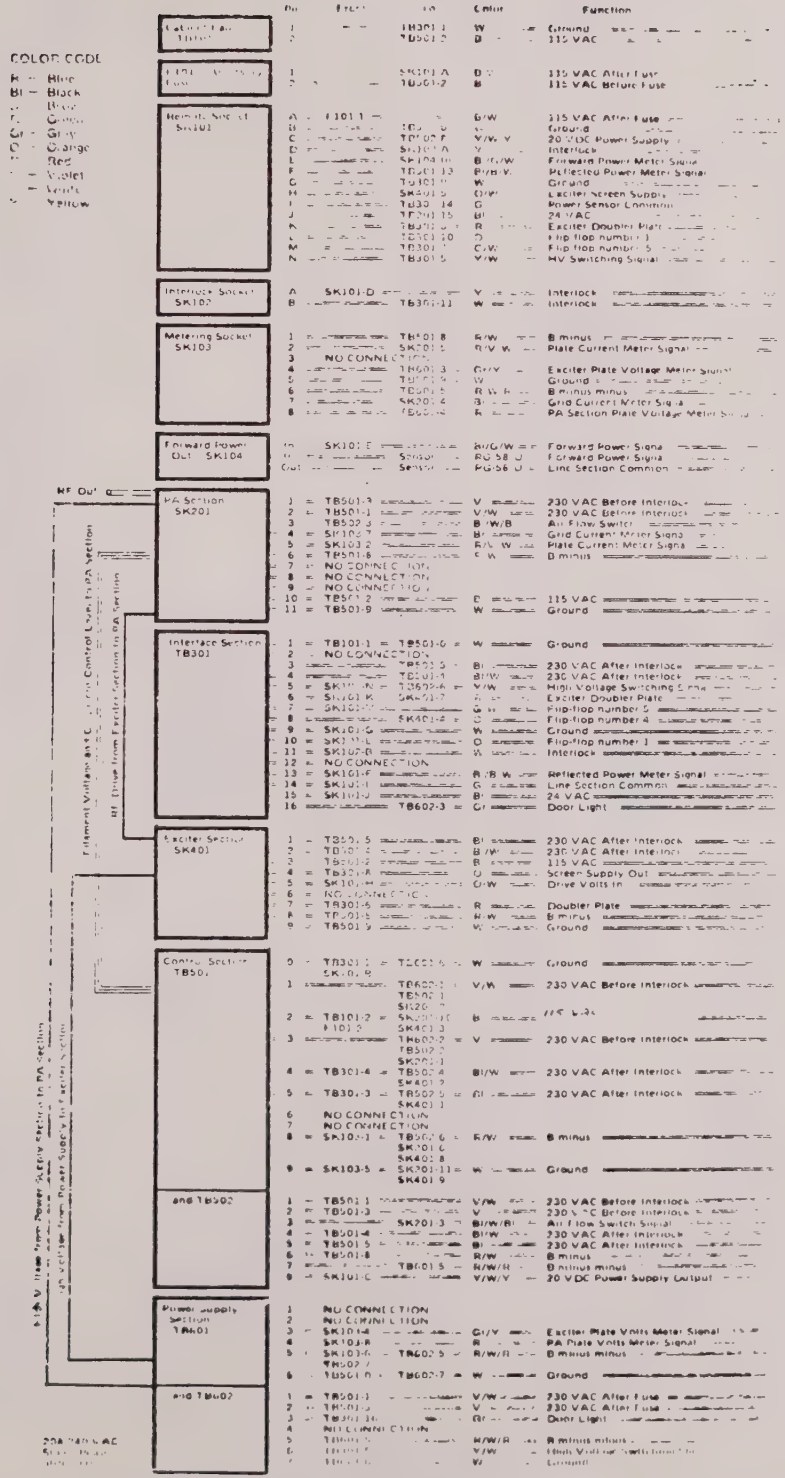


NOTES: (UNLESS OTHERWISE SPECIFIED)

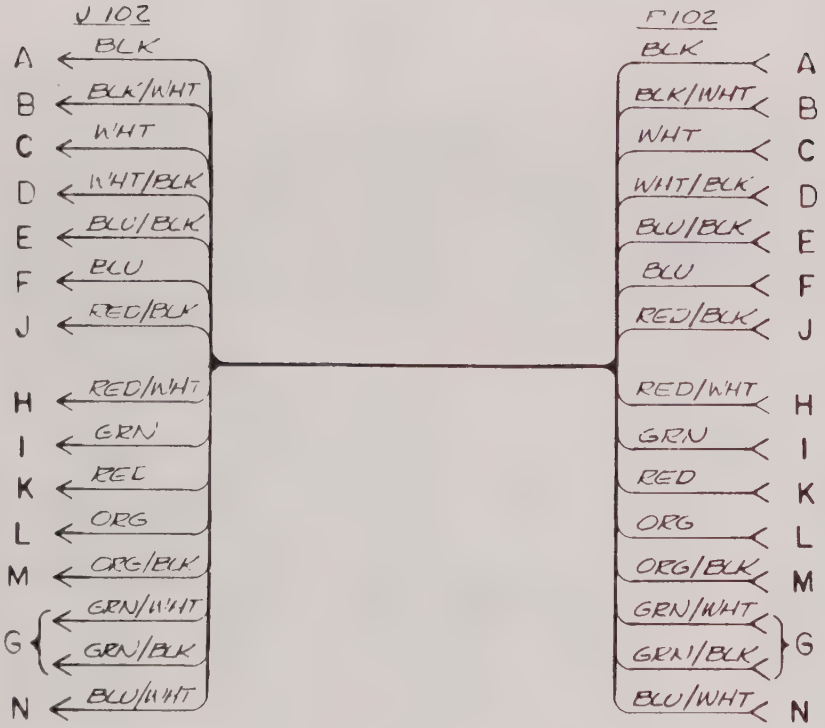
1. ALL RESISTOR VALUES ARE IN OHMS, AND ½ W
2. ALL DIODES ARE IN4003
3. ALL TRANSISTORS ARE 2N697

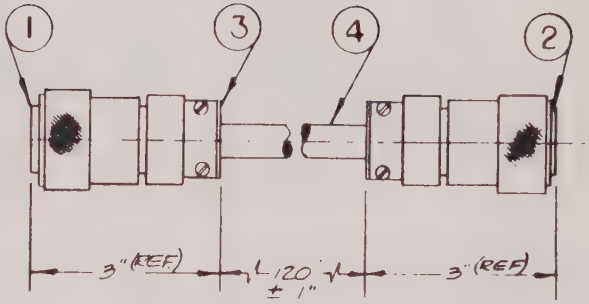
B 720-171-000 Flip-Flop Schematic

C 221-126-400 Harness Interconnect, 1000 W/2000 W



B 221-126-500 Harness Interconnect, 3000 W

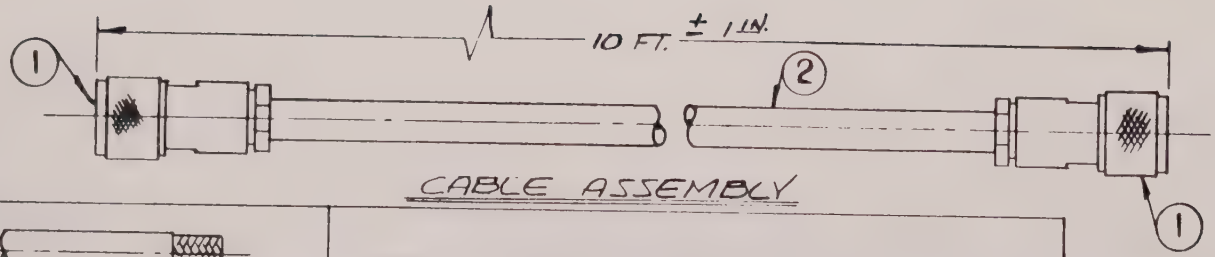




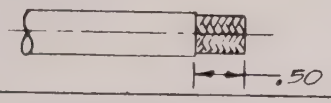
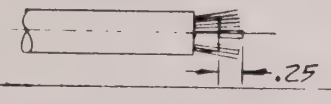
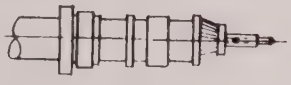
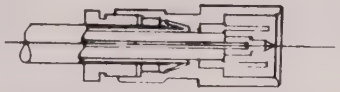
TEST PROCEDURE:

1. CONTINUITY TEST: USING VOM (ON RX1 SCALE) OR CIRCUIT TESTER CHECK PIN TO PIN THRU CONNECTOR FOR CONTINUITY.
2. SHORT TEST: USING VOM ON RX10,000 SCALE CHECK INDIVIDUALLY EACH PIN TO ALL OTHER PINS AND SHELL: METER SHOULD NOT MOVE.

ITEM	REQ	PART NUMBER	DESCRIPTION	REMARK/MAT'L
5	-	138 514 400	CABLE, BELDEN #8468	18 AWG 15 COND
4	2	139 422 400	BOOT #3420-12	
3	2	140 129 000	CLAMP AN 3057-12	
2	1	140 244 200	CONN AMP MS 3106A 20-27S	
1	1	140 244 000	CONN AMP MS 3106A 20-27P	



CABLE ASSEMBLY

	REMOVE 1/2" OF VINYL JACKET.
	COMB OUT COPPER BRAID AS SHOWN. CUT OFF DIELECTRIC 1/4" FROM END TIN CENTER CONDUCTOR.
	TAPER BRAID AS SHOWN. SLIDE NUT, WASHER AND GASKET OVER VINYL JACKET. SLIDE CLAMP OVER BRAID WITH INTERNAL SHOULDER OF CLAMP FLUSH AGAINST END OF VINYL JACKET.
	SLIDE BODY INTO PLACE CAREFULLY SO THAT CONTACT ENTERS HOLE IN INSULATOR. FACE OF DIELECTRIC MUST BE FLUSH AGAINST INSULATOR. SLIDE COMPLETED ASSEMBLY INTO BODY BY PUSHING NUT. WHEN NUT IS IN PLACE, TIGHTEN WITH WRENCHES.
	SMOOTH BRAID BACK OVER CLAMP AND TRIM. SOFT SOLDER CONTACT TO CENTER CONDUCTOR. AVOID USE OF EXCESSIVE HEAT AND SOLDER. SEE THAT END OF DIELECTRIC IS CLEAN. CONTACT MUST BE FLUSH AGAINST DIELECTRIC. OUTSIDE OF CONTACT MUST BE FREE OF SOLDER.

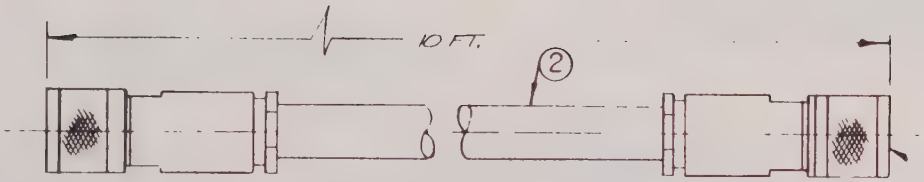
CONNECTOR ASSEMBLY INSTRUCTIONS

TEST PROCEDURE

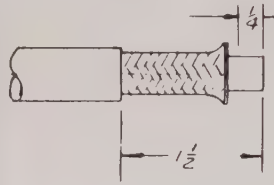
1. CONTINUITY TEST: USING VOM ON RX1 SCALE, CHECK CENTER CONDUCTOR TO CENTER CONDUCTOR AND CONNECTOR BODY TO CONNECTOR BODY. IN EITHER TEST, READING TO BE '0' OHMS.

2. SHORT TEST: USING VOM ON RX10,000 SCALE, CHECK CONDUCTOR TO CONNECTOR BODY. METER SHOULD NOT MOVE.

ITEM	REQ	PART NUMBER	DESCRIPTION
2	10 FT	181110000	COAX CABLE BELDEN #8237 RG8/U
1	2	140242900	CONN, AMPHENOL UG 21 B/U

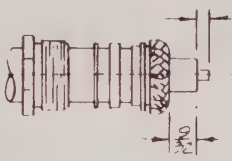


CABLE ASSEMBLY



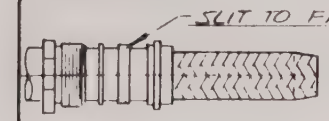
REMOVE 1-1/2" OF VINYL JACKET EVENLY ALL AROUND TEMPORARILY PUSH BACK BRAID ABOUT 3/8". CUT OFF CENTER CONDUCTOR AND DIELECTRIC 1/4" FROM END.

STEP 1



FOLD BRAID BACK OVER CLAMP TIGHTLY, CUTTING OFF EXCESS AND TRIM. DON'T UNBRAID. MEASURE 9/32" FROM BRAID AND REMOVE EXCESS DIELECTRIC EVENLY ALL AROUND, DO NOT NICK CONDUCTOR. MEASURE 1/8" FROM DIELECTRIC AND CUT OFF EXCESS CONDUCTOR. SOFT SOLDER CONTACT TO CENTER CONDUCTOR AVOID USE OF EXCESSIVE HEAT AND SOLDER. OUTSIDE OF CONTACT MUST BE FREE OF SOLDER DIELECTRIC MUST BE CLEAN.

STEP 3



SMOOTH BRAID BACK OVER CUT-OFF END AS SHOWN. SLIDE NUT AND FLAT WASHER OVER VINYL, SLIDE GASKET WITH GROVE TOWARD END OVER VINYL. CAREFULLY SLIDE CLAMP OVER BRAID WITH INTERNAL SHOULDER FLUSH AGAINST END OF VINYL JACKET (TAPER SIDE AWAY FROM END).

STEP 2

SLIDE BODY INTO PLACE CAREFULLY SO THAT CONTACT ENTERS HOLE IN INSULATOR. FACE OF DIELECTRIC MUST BE FLUSH AGAINS INSULATOR. SHOULDER OF CONTACT MUST BE FLUSH WITH RIM OF INSULATOR SLIDE COMPLETED ASSEMBLY INTO BODY BY PUSHING NUT. WITH WRENCHES, TIGHTEN BY HOLDING BODY AND TURNING NUT.

STEP 4

CONNECTOR ASSEMBLY INSTRUCTIONS

ITEM	REQ	PART NUMBER	DESCRIPTION	REMARK/MAT'L
2	122"	178152300	COAX CABLE RG 14 A/U	
1	2	140309000	CONNECTOR UG 491 A/U	

TEST PROCEDURE

1. CONTINUITY TEST: USING VOM ON RX1 SCALE, CHECK CENTER CONDUCTOR TO CENTER CONDUCTOR AND CONNECTOR BODY TO CONNECTOR BODY. IN EITHER TEST, READING TO BE '0' OHMS.

2. SHORT TEST: USING VOM ON RX10,000 SCALE, CHECK CONDUCTOR TO CONNECTOR BODY. METER SHOULD NOT MOVE.

Univ. Texas, X 7424

OPERATING and MAINTENANCE INSTRUCTIONS FOR HIGH ACCURACY 170 SERIES SENSOR HEADS

MKS Instruments, Inc.
22 Third Avenue
Burlington, Mass. 01803
617-272-9255

MKS INSTRUMENTS, INC.

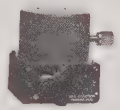
WARRANTY

MKS Instruments, Inc. (MKS) warrants that all equipment manufactured by **MKS** shall be free from defects in materials and workmanship for a period of one year from date of shipment. For the period commencing with the date of shipment of the equipment and ending one year later, **MKS** will, at its option, either repair or replace any part which is defective in materials or workmanship without charge to the purchaser. The foregoing shall constitute the sole remedy of the purchaser for any breach by **MKS** of this warranty.

The purchaser, before returning any equipment covered by this warranty, which is asserted to be defective by the purchaser, shall make specific written arrangements with respect to the responsibility for shipping the equipment and handling and other incidental charges, with the **MKS** sales representative or distributor from which the equipment was purchased, or in the case of a direct purchase, from **MKS** home office in Burlington, Massachusetts, USA.

The warranty does not apply to any equipment which has not been used in accordance with the specifications recommended by **MKS** for the proper and normal use of the equipment. **MKS** shall not be liable under any circumstances for consequential or incidental damages in connection with, or arising out of the sale, performance or use of, the equipment covered by this warranty.

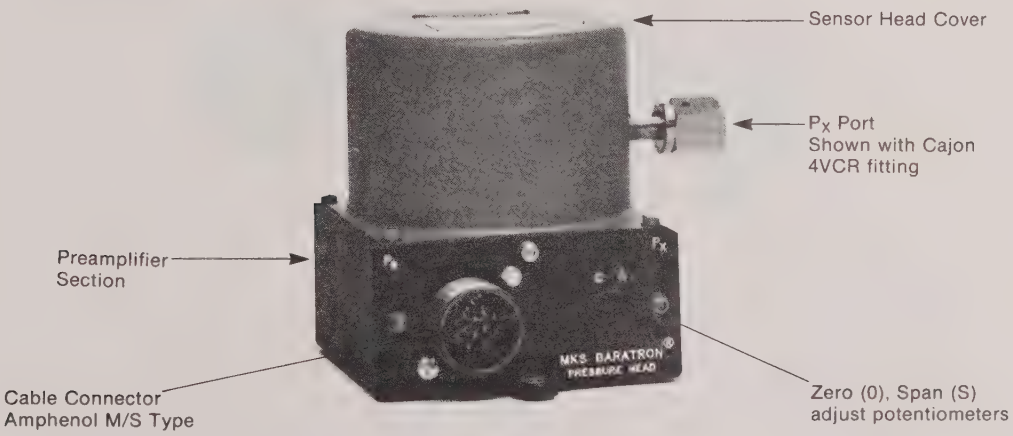
THIS WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES BY **MKS,** EXPRESSED OR IMPLIED, INCLUDING WARRANTIES OF MERCHANTABILITY, WARRANTIES OF FITNESS FOR A PARTICULAR PURPOSE AND WARRANTIES AGAINST INFRINGEMENT OF ANY PATENT.

MKS BARATRON® HIGH ACCURACY SENSOR HEAD SELECTION GUIDE	STD-Temp Controlled	High Line Pressure	STD-Bakeable	FAST Response
				
Sensor Head Model Number	310	308	315	317
Type of Measurement	Absolute—310BHS Differential Gage } 310BH	Differential Gage } 308H	Absolute—315BHS Differential Gage } 315 BH	Absolute—317HS Differential Gage } 317H
Sensor Type	Single-Sided	Single-Sided	Single-Sided	Single-Sided
Measurement Side (Px) **Media Compatibility** **Volume**	Any gas compatible with Inconel, 304SS 2 cc	Any gas compatible with Inconel, 304SS 2 cc	Any gas compatible with Inconel, 304SS 2 cc	Any gas compatible with Inconel, 304SS 16 cc
Reference Side (Pr) **Media Compatibility** **Volume**	Any dry gas compatible with Inconel, 304SS, Fosterite, Palladium 5 cc	Any dry gas compatible with Inconel, 304SS, Fosterite, Palladium 8 cc	Any dry gas compatible with Inconel, 304SS, Fosterite, Palladium 5 cc	Any dry gas compatible with Inconel, 304SS, Fosterite, Palladium 5 cc
Accuracy	STD: 0.08% of Reading ±zero/span coeff. OPT: 0.05% of Reading ±zero/span coeff.	0.1% of Reading ±zero/span coeff.	0.08% of Reading ±zero/span coeff.	0.1% of Reading ±zero/span coeff.
Temperature Effects on Zero/Span	< 5 ppm FS/°C (temp. controlled @ 45°C) 0.002%R/°C	≤ 5 ppm FS/°C (temp. controlled @ 45°C) ≤ 0.002% R/°C	< 15 ppm FS/°C (temp. controlled) < 0.003% R/°C	≤ 40 ppm FS/°C (temp. controlled) < 0.003% R/°C
Temperature Operating Range	Ambient to 45°C Temperature Regulated	Ambient to 45°C Temperature Regulated	Absolute: Ambient to 200°C Differential: Ambient to 450°C	Ambient to 200°C
Pressure Range F.S. **Useable Resolution (decades)**	1, 10, 100, 1000, 10000 Torr 5	1, 10, 100, 1000 10000 Torr 5	1, 10, 100, 1000 10000 Torr 5	1, 10, 100, 1000 10000 Torr 4
Max Line Pressure	150 psig	2000 psig	150 psig	150 psig
Line Pressure Effects on Zero	10 Torr and higher 0.008%FS/psi 1 Torr 0.02%FS/psi	0.03%FS/2000 psi	Same as 310	Same as 310

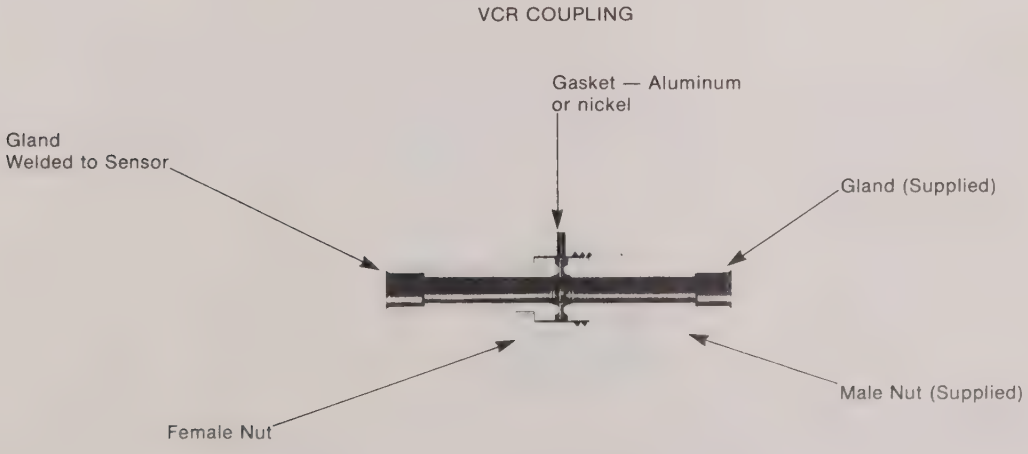
170 SERIES HIGH ACCURACY SENSOR HEADS

A High Accuracy Sensor Head consists of a diaphragm type variable capacitance pressure transducer and electronic preamplifier either as an integral temperature controlled package or as a pressure transducer connected to a separate preamplifier with high temperature cables. Each Sensor Head package is individually calibrated against NBS Traceable Factory Standards, and Certificates of Traceability are available upon request.

Pressure Connections/Temperature Controlled Integral Sensor Head Units — Types 145, 310, 308.



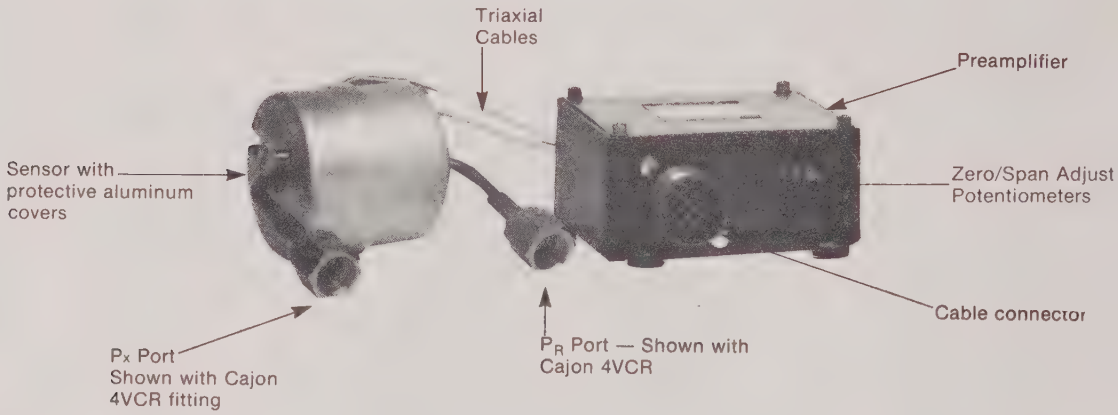
Each pressure port — P_X on absolute units and P_X and P_R on differential units — is normally shipped with Cajon type pressure connectors and mating half as shown below:



Other vacuum/pressure fittings are available upon order as well as adapters from one type to another — consult factory.

The P_X port is usually connected to the unknown pressure to be measured, while the P_R port is connected to the lower pressure or reference side. A differential sensor head can be used to make absolute pressure measurements by continuously pumping the reference side to a low pressure below the resolution of the sensor. In the manufacturing process for absolute transducers, the reference side is vacuum pumped for long periods to ultra-high vacuum levels while at high temperature to facilitate the outgassing and cleanup procedure. After processing, the reference side is "pinched-off" via a soft copper pinch-off tube, and a chemical getter is activated to continue the vacuum pumping throughout the lifetime of the instrument.

Pressure Connections High-Temperature Bakeable Sensor Head Units — Types 94, 315, 317.



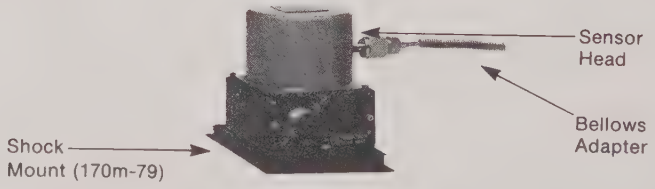
Each pressure Port is normally shipped with Cajon 4VCR Fittings and mating halves. As with the temperature regulated Sensor Heads, other vacuum fittings are available upon order.

Note: Proper Triaxial cable connections are indicated on the preamplifier, i.e. J_X connects to the P_X side of the sensor, while J_R connects to the P_R side of the sensor.

CAUTION: THE TRIAXIAL CABLES ARE SENSITIVE TO CAPACITIVE PICKUP, HENCE SHOULD BE SOLIDLY AFFIXED TO SOME SURFACE, AND OPERATING PERSONNEL SHOULD AVOID TOUCHING OR HANDLING THE CABLES WHILE PRECISION MEASUREMENTS ARE BEING MADE WITH THE MKS PRESSURE SENSOR UNIT.

TECHNIQUES FOR OPTIMIZING SENSOR HEAD MEASUREMENT PERFORMANCE

Vibration and Strain Isolation — Since capacitance manometer sensors are highly accurate electro-mechanical devices, and subject to influence by excessive vibration or mechanical strain on the port(s), it is recommended that the sensor head (particularly low range units such as 1 mmHg full scale) be shock mounted on a plate using commercially available shock mounts such as Barry (275-2), and coupled to the processing chamber through flexible bellows couplings as shown below:



Do not mount the head in a manner which causes the weight of the head to be transmitted to the port(s). Use the three mounting holes provided on the head base casting.

Vibration due to mechanical type vacuum pumps can affect the accuracy of pressure measurement and control, and typically will occur as 120 Hz noise riding on the DC output signal. If such noise (vibration) is suspected, connect an oscilloscope to the DC output connectors of the Electronics Unit (170M-6B) and look for 120 Hz noise on the DC output signal. Momentarily shutting off the mechanical pump will help to determine if this is the problem.

ZERO AND SPAN ADJUSTMENTS

The span of the sensor head is factory set during the calibration and should never be adjusted by the user unless there are available transfer or primary standards to aid in recalibration. If the span potentiometer in the sensor head preamplifier is mistakingly adjusted, please contact the MKS home office for assistance, and possibly instructions to return the instrument to MKS for recalibration.

After the sensor head has been installed on the system whose pressure is to be measured, it must then be connected to the electronics Unit (170 Series) via a standard head cable — MKS part no. CB 036. Once power is applied to the Electronics Unit, a minimum time of four hours and preferably overnight should be allowed for the heater in the sensor head package to thermally stabilize the sensor prior to attempting a zeroing procedure. This is only necessary for sensor heads having built in temperature regulation. For bakeable sensors (Types 94, 315, 317) it is adviseable to temperature control with an MKS temperature controller or with a customer designed thermally stabilized enclosure in order to minimize the effects of ambient temperature change on the sensor zero. If the bakeable sensor is temperature controlled, then again follow the above stabilization procedure as for temperature regulated units.

The user should first attempt to zero the sensor head with the coarse zero potentiometer on the front panel of the appropriate 170 Series Electronics Unit (e.g. 170M-6B), and if this is not possible, then use the following procedure: Set the coarse zero pot on the Electronics Unit front panel at its mid point (10 turn pot), then remove the snap plug on the sensor head preamplifier allowing access to the very coarse zero pot. With an instrument screwdriver, set the coarse zero. Then finish the zeroing procedure with the Electronics Unit.

Please Note: an absolute sensor must be at a pressure below its minimum useable resolution in order to set the zero, and a differential sensor must have equal pressure on both sides.

It is a common requirement for the user to set the coarse zero on the sensor preamplifier when a sensor is first installed on a system, since during the calibration procedure at the MKS factory, the sensor is oriented in some orientation, e.g. the diaphragm might be vertical. If the user were to mount the sensor in his system with the plane of the diaphragm in other than the vertical direction, then the factory set zero would not be valid. Installation orientation does in no way affect the sensor calibration, but the user must zero the sensor in his particular installation.

Note: All diaphragm type variable capacitance pressure transducers require the user to set zero. The frequency of setting zero will depend on use, variations in ambient temperature, and application. The user will, with experience, gain a feeling for the frequency with which the zero adjustment must be made. For extremely critical measurement of very low pressures, checking the zero more often and making minor adjustments will insure the most accurate measurements attainable with the MKS Baratron®.

The adjustment of the sensor zero has no effect on the factory calibration, and should be set at the actual operating temperature of the sensor (e.g. sensors operated above the normal temperature controlled value of 45° C).

TROUBLE SHOOTING GUIDE

SYMPTOM	CAUSE	REMEDY
CANNOT ZERO		
a. With absolute Head	Pressure differential	Pump down Px side.
b. When power first applied	Head not at operating temperature (Temp. regulated Heads only)	Allow time for stabilizing. (4-6 hours)
c. On most sensitive ranges	Amplifier overload	Go back to less sensitive range until on scale and try again.
d. At end of zero pot range (after warmup)	System zero has shifted.	Adjust coarse zero control at Head to bring Indicator control in range. Center ZERO ADJ. on Indicator first.
e. Zero offset at or near full scale on least sensitive ranges.	Shorted sensor, open or short in Head cable	Substitute Head or Cable if available.
ZERO SHIFT		
a. After applying power	Sensor temperature drift	Allow 4 to 6 hours for sensor thermal stabilization, 24 hours for optimum stability.
b. When changing from atmospheric to vacuum operation	Different outgassing rates for Px and P_R at vacuum	Allow time for outgassing completion.
c. When either raising or lowering line pressure	Leaks in vacuum system	Check pressure connections at Head and other fittings.
d. Upon turn on of RF power in, for example, a sputtering system. Sudden "negative going" pressure reading.	Pick up in Sensor Preamplifier	Replace standard sensor head cable with shielded version or relocate sensor on system.

SENSOR HEAD SIMULATOR TYPE 170M-80

DESCRIPTION

The type 170M-80 Head Simulator simulates the sensor head in a 170 Series High Accuracy Pressure Measurement system for purposes of system check out and trouble-shooting. The Simulator will simulate any sensor head which operates with a type 170M-6B Electronics Unit.

FEATURES

Replaces sensor head permitiing checking of:

- Heater Power Supply
- Preamplifier Input Voltage
- Zero Output
- Full Scale Output
- Linearity at 50% of Full Scale Output
- Oscillator Ampiitude
- Sensor Malfunction

APPLICATIONS

Identifies faulty Sensor Heads
Checks Electronics Unit operation
Checks Head Cables
Allows full scale adjustment for optimum long cable operation

TYPE SENSOR HEADS SIMULATED

Any Sensor Head that operates with type 170 indicators may be simulated by the type 170M-80. Basic Sensor head types which may be simulated are: 94, 145, 300, 305, 310, 315, 308, 146, 317.

COMPATIBLE TYPE INDICATORS

The simulator is designed to replace heads in indicator systems which provide a 0-10 VDC output per range. Basic type indicators compatible with the simulator are: 170M-5, 170M-6, 170M-7, 170M-9, 165M and 210M.

TEST EQUIPMENT REQUIRED

A high accuracy AC voltmeter is required if the oscillator amplitude (6.000 VRMS) on the 170M-6B is to be checked.

DIMENSIONS

Approximately 2½" × 3" × 1¾"

OPERATING INSTRUCTIONS

SYSTEM CHECKOUT

Disconnect the head cable from the sensor and connect it to the connector on the simulator. The red lamp should be on, indicating that the proper pre amp voltage is present at the end of the cable. When the switch is placed in the zero position a zero signal is developed across the signal input lines. In this position it should be possible to adjust the electronics unit for a stable zero on all ranges. When the switch is placed in the +10V position the simulator will produce a signal sufficient to produce a stable +10V (Full Scale) reading on the ×1 range.

The 170M-80 also contains a resistor to simulate the heater in the sensor. When the heater switch is placed in the REG. position the heater lamps on the electronics unit will come on if the heater supply is working properly. This lamp will not display the same brilliance as it does when attached to a heater due to the higher value of the simulator resistor.

ELECTRONICS UNIT RE-CALIBRATION

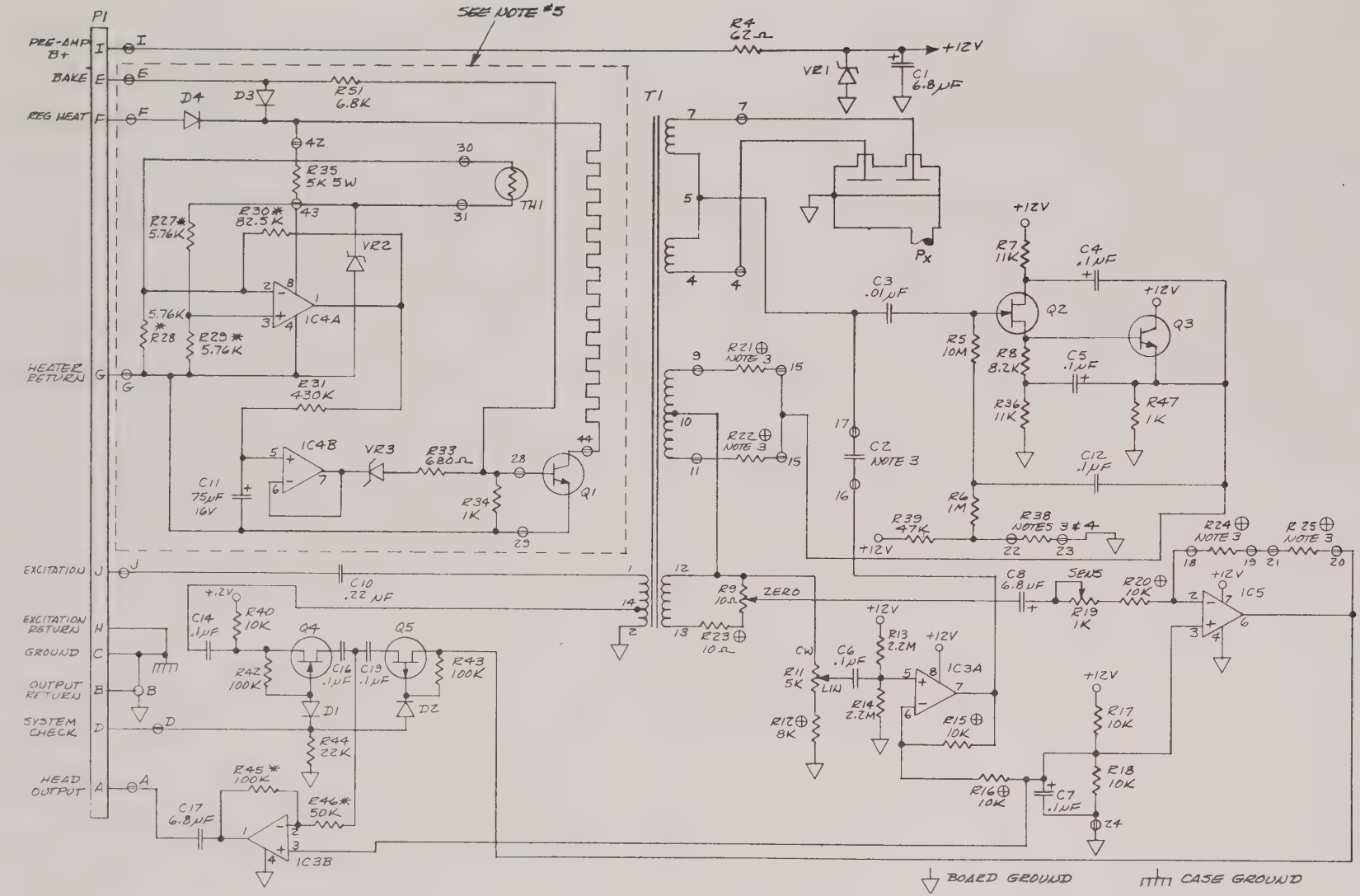
1. Connect a high accuracy AC meter to the jacks on the top of the simulator and measure the amplitude of the oscillator. The proper level is 6.000VRMS and it may be adjusted if necessary. The adjustment is accessible through the top cover on a 170M-6B. On other units the cover must be removed to expose the control of the oscillator/power supply board.

2. Place the simulator switch in the zero position, adjust the null on the indicator and then the zero on all ranges. Then place the range multiplier in the ×1 position. Place the simulator switch in the +10V position and adjust the full scale pot on the front of the electronics unit for a reading of +10.000 volts at the output of the electronics unit.

3. Place the simulator switch in the +5V position to check linearity at the 50% point. This should be within ±.05% of full scale.

OPTIMIZING LONG CABLE OPERATION

When long sensor head cables are used in a system frequently it is necessary to adjust the system gain to optimize system performance which might be degraded due to the cable length. When the simulator is installed on the end of the sensor head cable the system gain is adjusted by using the procedures above. Note that on occasion the 170M-6B Electronics Unit span adjust (reached through a slot in the cover) may have to be adjusted if the full scale adjustment is insufficient to set full scale.



C-103676 310 and 315 Head Schematic Rev E

PERKIN-ELMER Plasma Products Division
P.O. Box 10920, Palo Alto, CA 94303. PHONE: (415) 967-2100. TWX: 910-373-6442